The Human Dentition in Forensic Medicine: Symposium*

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Time and Sequence of Tooth Eruption**

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It is easily proven that not only men in various branches of science but even laymen all over the world have looked upon the dentition as a convenient indicator of age.

Youatt (1), for instance, touches on the matter in his popular treatise published in 1834, pointing out that the inspection of teeth was of value in determining the age of cattle. The legal value of the dentition was clearly appreciated by Saunders (2), who in 1837 urged members of the English Parliament to use the teeth as a criterion of age to facilitate the enforcement of certain child labor regulations. That the Japanese had for centuries been aware of the correlation between dental status and age is revealed by the written charac-

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ter for the latter, in general use until World War II. This consisted of two main parts, the first of which was the ancient symbol for "tooth."

Without doubt much more use of the teeth as a criterion of age would have developed were it not for the wide degrees of variation in the processes of tooth formation and eruption. For those engaged in forensic medicine the need for up-to-date information regarding variability in tooth eruption is something that need not be debated at all; the only questions of importance being those concerning the reliability and universality of such data as are presently available.

The essayist has reviewed the quantity and quality of much data bearing on the emergence of human permanent teeth. As a result of his surveys in 1948 and 1949 he was able to summarize the best statistical material that had come to his attention, and to publish standards of variation for all classes of permanent teeth, excepting the third molars, or wisdom teeth (3, 4). These standards represent painstaking study of data on close to 100,000 children, and have been of interest to people in dentistry, medicine, anthropology, and legal medicine all over the world. They have been utilized in the preparation of certain tabulations in the recently published Handbook of Biological Data (5).

For experts in forensic medicine the figures of most interest are those which deal with the 95 per cent range of emergence of human permanent teeth, since this range corresponds rather closely with the plus and minus limits of 2 standard deviations from the mean. In estimating the age of remains of children or young adults the 95 per cent range can be looked upon as providing the most likely upper and lower extremes of an estimate, anything outside this range being of distinctly unusual occurrence.

A glance at Table I shows that the minima and maxima at the 95 per cent level are quite far apart, ranging from a little over 3 years to more than 6½ years, not counting the third molars. Thus the chances of error are considerable in using teeth for purposes of estimation of age, and the desirability of supplementing this estimate with evidence of some other kind becomes easy to understand. It is more than obvious, too, that attempts to base the age estimate upon utili-

zation of conventional tooth eruption tables, such as are included in most dental and medical textbooks, may lead the medicolegal investigator quite far astray.

TABLE I

NORMAL VARIABILITY IN EMERGENCE OF HUMAN PERMANENT TEETH

Sequence	Tooth		95 per cent range (Years)						Sex diff. (yr.)
	Max.	Mand.	Boys			Girls			
1	—	M_1	4.64	–	7.78	4.37	–	7.51	.27
2	M_1	—	4.83	–	7.97	4.65	–	7.79	.18
3	—	I_1	5.01	–	8.07	4.73	–	7.79	.28
4	I_1	—	5.88	–	9.06	5.61	–	8.79	.27
5	—	I_2	5.98	–	9.42	5.62	–	9.06	.36
6	I_2	—	6.75	–	10.59	6.28	–	10.12	.47
7M 8F	Pm_1	—	7.52	–	13.28	7.15	–	12.91	.37
+									
8M 7F	—	C	8.30	–	13.28	7.37	–	12.35	.93
+									
9	—	Pm_1	7.94	–	13.70	7.30	–	13.06	.64
10	Pm_2	—	8.10	–	14.26	7.80	–	13.96	.30
11	—	Pm_2	8.18	–	14.76	7.60	–	14.18	.58
12	C	—	9.00	–	14.38	8.29	–	13.67	.71
13	—	M_2	9.45	–	14.79	8.99	–	14.33	.46
14	M_2	—	9.99	–	15.37	9.58	–	14.96	.41
15	—	M_3	16.5(?)	–	27.0(?)	16.5(?)	–	27.0(?)	small
16	M_3	—	16.5(?)	–	27.0(?)	16.5(?)	–	27.0(?)	small

If the sex of human remains is not known, the error in estimating age can be from 2 to 11 months more than it would be otherwise, depending on the morphological classification of the particular teeth that happen to furnish the most useful information to the examiner in a given case. This source of error must be eliminated, therefore, whenever possible. In this connection it appears appropriate to recall the technic devised by Hunt and Gleiser (6) in 1955. By making concurrent estimates of both bone and dental age of preadolescent remains, it becomes possible to compare the two. The estimates "by male standards should agree closely if the remains are those of a boy, but should be more divergent if female standards are applied. The opposite is usually true if the remains belong to a girl."

Another hint regarding sex may be secured by noting the sequence of emergence in the permanent canine and first premolar regions. The largest time difference in the emergence of teeth in boys and girls is furnished by the mandibular canine, which appears about 11 months earlier in the average girl than in the average boy.

From the above it follows that whereas the sequence in the emergence of first premolars and mandibular canine is, ordinarily, (1) mandibular canine, (2) maxillary first premolar and (3) mandibular first premolar in girls, or nearly simultaneous appearance of all three teeth, in boys the maxillary first premolar almost always precedes the other two, and the three teeth seldom pierce the gingivae in unison, or nearly so.

The sex difference in the eruption time is quite marked for the permanent maxillary canine also. As a general rule it may be said that preadolescent remains showing this tooth close to, or ahead of, the maxillary second premolar in development belong to a female rather than a male.

Notwithstanding the generalizations just made it must be recognized that the question of sequence in the eruption of canines and premolars has never been fully elucidated. Even if it is assumed that the statistics furnished by Hurme (3, 4) in Table I are reasonably reliable, it is still necessary to remember that, since they are statistics on *pooled* observations, or data on *groups,* they cannot furnish much information on the sequence of tooth eruption in isolated individuals. Deviations from general averages are not rarely quite astonishing, and an excellent illustration of this is afforded by the order of emergence of the permanent second premolars and second molars.

According to Table I, and countless other tables of tooth eruption, second molars *follow* second premolars in eruption.

Just prior to this symposium the author conducted a survey of the long-term dental records of 95 males and females followed from birth to about 18 years of age in the study of human growth and development at the School of Public Health, Harvard University, under the direction of Dr. Harold C. Stuart (7). A sizeable percentage of these records furnishes no unequivocal information on the sequence of emergence of second premolars and second molars, as the interval between

successive examinations had been too long. Nevertheless, out of the 380 mouth quadrants examined 51, or 13.4 per cent, presented earlier emergence of the second molar than of the second premolar. If some allowance is made for the probability of an M_2 Pm_2 sequence among the 76 mouth quadrants for which no conclusive data were available, it would appear that the M_2 Pm_2 sequence should be expected in about 17 per cent of all cases among Whites. In other words, this supposedly primitive sequence is not at all rare in modern man.

According to a recent personal communication from Dr. S. M. Garn (8), at the Fels Research Institute, analysis of Hrdlicka's 1908 data on the American Indian reveals the M_2 Pm_2 sequence "as common or more common [than] the Pm_2 M_2 sequence. . . in Whites."

The story of eruption of third molars, or wisdom teeth, still remains to be written. Until certain analyses now going on have been completed and published, it will be impossible to speak authoritatively about biometric data on the third molar.

Two aspects of third molar eruption can be discussed in a tentative manner, nevertheless. Undoubtedly the more interesting of these is the probable nonexistence of any striking difference in the emergence times of these teeth in males and females. If this conjecture is verified by documented material at a future date, it means that medicolegal experts will never derive much joy from an inspection of third molars in trying to determine the sex of adolescent or young adult skeletal remains.

The less surprising aspect of third molar data relates to the very wide range of seemingly normal variation that is encountered. Although the figures for this tooth as given in Table I represent much more guesswork than is desirable, they do serve to convey some idea of the widely spread frequency distributions. Estimates of chronological age on the basis of third molar eruption alone will always be risky.

The applicability of permanent tooth eruption standards for Whites or other racial groups remains uncertain. Largely unverified data on African Blacks (9a) certainly suggest that the eruptive process takes place from one-half to one and a half years earlier in the Negro than in the European or American White (9). As for the Mongolian ethnic groups there

appears to be no striking difference between Whites and Japanese, judging from a few Japanese reports that have been seen by the writer. The one possible exception to the above statement will be pointed out later.

Odontologic literature written in the English language is almost completely devoid of authoritative studies devoted to the subject of interracial relationships in tooth eruption. In order to remedy this situation to some degree, two of the best Japanese reports that have come to the attention of the author will be discussed in some detail.

The paper by Okamoto (10), published in 1934, contains surprisingly complete listings of statistical values, some of which are shown in Tables II and III. The emergence means supplied by Okamoto, who *personally* examined no less than 11,257 children from 3 to 16 years of age, are, with the exception of only 4 pairs of values, within 0.35 of a year of the figures for Whites. About 50 per cent of them are above, and

TABLE II

EMERGENCE OF PERMANENT TEETH IN WHITES AND MONGOLIANS

(Years)

Tooth		Caucasians			Japanese					
		Hurme – 1949			Determined from data by Nagamine – 1933			Okamoto – 1934 (without verification)		
		Mean			Median + 0.50 yr.*			Mean		
Max.	Mand.	M	F	S.D.	M	F	S.D. (est.)	M	F	S.D. (av.)
—	M_1	6.21	5.94	0.80	6.35	6.10	0.80	6.39	6.09	1.13
M_1	—	6.40	6.22	0.80	6.75	6.55	0.80	6.76	6.63	1.18
—	I_1	6.54	6.26	0.78	6.90	6.70	0.78	6.75	6.56	1.19
I_1	—	7.47	7.20	0.81	7.95	7.65	0.88	7.63	7.26	1.18
—	I_2	7.70	7.34	0.88	7.85	7.60	0.80	7.65	7.39	1.32
I_2	—	8.67	8.20	0.98	9.20	8.80	0.89	8.97	8.44	1.36
Pm_1	—	10.40	10.03	1.47	10.45	9.95	1.46	9.89	9.55	1.67
—	C	10.79	9.86	1.27	10.80	9.95	1.00	10.38	9.49	1.54
—	Pm_1	10.82	10.18	1.47	10.80	10.20	1.45	10.51	9.91	1.75
Pm_2	—	11.18	10.88	1.57	11.55	11.15	1.55	10.97	10.67	1.66
—	Pm_2	11.47	10.89	1.68	11.60	11.15	1.56	11.47	10.87	1.94
C	—	11.69	10.98	1.37	11.60	10.80	1.27	10.99	10.52	1.52
—	M_2	12.12	11.66	1.36	12.30	11.65	1.34	12.29	11.68	1.72
M_2	—	12.68	12.27	1.37	12.90	12.35	1.39	13.01	12.59	1.57

* Means are 0.05 to 0.10 yr. higher than medians.

50 per cent below, the values given by Hurme. The standard deviations, however, are peculiarly high, especially for the first six permanent teeth, when contrasted with Hurme's values. Another strange feature in Okamoto's report is the appearance of some *negative* values in the frequency distributions.

TABLE III

SEX DIFFERENCES IN THE EMERGENCE OF PERMANENT TEETH IN WHITES AND MONGOLIANS

Females earlier than males (decimals of a year)

Tooth		Caucasians	Japanese	
Max.	Mand.	Hurme	(Computed from) Nagamine	Okamoto (unverified)
—	M_1	0.27	0.25	0.30
M_1	—	0.18	0.20	0.13
—	I_1	0.28	0.20	0.19
I_1	—	0.27	0.30	0.37
—	I_2	0.36	0.25	0.26
I_2	—	0.47	0.40	0.53
Pm_1	—	0.37	0.50	0.34
—	C	0.93	0.85	0.89
—	Pm_1	0.64	0.60	0.60
Pm_2	—	0.30	0.40	0.30
—	Pm_2	0.58	0.45	0.60
C	—	0.71	0.80	0.47
—	M_2	0.46	0.65	0.61
M_2	—	0.41	0.55	0.42

Nagamine's (11) article detailing the results of an examination of 11,755 youngsters ranging in age from 3 to 20 years supplies no means and standard deviations for the various classes of teeth, but it is possible to estimate them from the cumulative percentages tabulated in the report. For the present purpose only the medians were determined, since they are easy to obtain by graphing, and are only slightly below the means. Approximate standard deviations were estimated from the same graphs.

It was evident at once that the medians derived from Nagamine's (11) data would be very similar to the means of Okamoto (10), as well as those of Hurme (4), if 0.50 of a year were added to each value. The augmented values are given in Table II.

Five reasons can be listed for favoring the provisional acceptance of these augmented means: (1) a 6-months ambiguity in the age classification of statistical material is very common in dental literature, and is due to a failure to define precisely the age limits employed; (2) the half-year correction makes the medians more harmonious with the ranges of variation given by Nagamine (11) himself, as well as with the conclusions drawn by him; (3) there is no readily available evidence to suggest that the emergence of teeth in Japanese is consistently earlier than in Whites; (4) not to apply the 0.50 year correction to Nagamine's figures would mean almost certainly that Okamoto's (10) statistics are largely erroneous; and (5) this is a tentative evaluation, rather than an exhaustive critical analysis.

Of special interest is the finding that the approximate standard deviations obtained from Nagamine's (11) material agree far better with those given by Hurme (4) than with those calculated by Okamoto. It is not possible to state categorically, without thorough review of the entire report, whether Okamoto's (10) standard deviations were calculated properly; the only definite assertion that can be made is that most statistics on tooth eruption are seriously defective and need close scrutiny before they can be accepted with confidence for purposes of comparative study.

The Japanese data, no matter how evaluated, suggest that the maxillary canine emerges earlier in Japanese than in Caucasians, on an average. They also confirm the belief that, ignoring the third molars, the mandibular second premolar is the most unstable dental organ as regards the chronology of final stages of eruption.

Table III indicates the close parallelism between Caucasians and Japanese in the matter of sex differences in permanent tooth emergence. Without doubt the mandibular canine furnishes the best single clue to the sex of the owner of a dentition.

The question has been asked quite frequently whether any universal norms have been developed for the emergence of deciduous or milk teeth. The answer to this question is definitely a negative one. Dentists in this country and in Europe have, by and large, paid very little attention to the first few

years of human development. The writer believes that he has made a fairly thorough survey of the literature dealing with the eruption of deciduous teeth. He also has reanalyzed the clinical records available at Harvard University. It is his opinion that enough material does exist today to permit the development of eruption norms for the primary dentition. This task is a difficult and time-consuming one, however, due to various peculiarities that characterize some of the publications on deciduous tooth emergence.

Several points of interest have been revealed by the study of odontiasis in the "rhesus" monkey, which has a dentition that is very similar to the human. The carefully kept records on serial observations that have included the teeth, at Yale University School of Medicine, have been invaluable for learning more about dental maturation in this primate and the author is grateful to Dr. G. van Wagenen (12, 13) for placing these records at his disposal.

The point of perhaps the most immediate interest to medicolegal people is the finding that if serial dental records are kept on an infant, or a child, it may be possible to arrive at a fairly close estimate of his chronologic age. In other words, after adequate eruption norms have been developed for the human deciduous dentition, by keeping good records on teething it should be possible to calculate the birth date of a war orphan, or a foundling, who has no official birth certificate. The author has tried the procedure on a few young macaques, who had only about one-half of their teeth visible at the time of their fictitious arrival into the monkey laboratory, and he has found his calculated birth dates to fall within less than a week of the true birth dates.

Estimates of this kind are possible because the individual teeth of a dentition do not emerge completely at random, in spite of the seemingly erratic behavior of an occasional tooth or tooth pair. Each organism has its basic rate of dental development, which is not readily altered, so that it is essentially the same from one age period to another. Nevertheless, in using teeth as age indicators, it is well to remember that reliance on only one or two teeth may be very misleading, since the one or two teeth observed may be the very ones that are the least representative of the entire dental complex.

The macaque studies have established also the fact that there is a relationship between the timing of teething and the length of gestation. The longer the period of pregnancy the sooner after birth are teeth likely to appear, and vice versa. This observation may be of some medicolegal interest in certain cases of contested paternity of a child, as it is known that there are remarkable variations in length of pregnancy in different women. In a few instances the period of pregnancy may be so long as to cast serious doubt on the woman's claim regarding paternity; if the first teeth of the child are known to have emerged unusually early, she will have supporting evidence of the plausibility of her claim. This aspect of the onset of tooth emergence is not so well known as is the observation that premature babies tend to get their teeth later than average.

The one practical problem that remains, of course, is the dental education of pediatricians and nurses. All too often these good people see everything else about an infant *except* his teeth, unless the infant bites someone.

Summary

1. Use of teeth as a criterion of age can be misleading to the medicolegal expert, as the tables of eruption available in textbooks generally ignore the remarkable variability of the process of teething.
2. The author recommends use of the 95 per cent range derived from his analyses of eruption data on almost 100,000 White children. This range provides the most likely upper and lower extremes of an estimate.
3. If the sex of human remains is not known, the error in estimating age can vary from 3 to 7½ years, ignoring third molar eruption.
4. Sex can be established with moderate success by making concurrent estimates of both bone and dental age, or by noting the sequence of emergence of teeth in the permanent canine and premolar regions. The lower canine is the most distinctly sex-linked member of the permanent dentition.
5. Deviations from the usual order of tooth eruption are frequent, the second premolars and second molars fur-

nishing an excellent illustration of variability in this respect.

6. Third molar data are not likely to be of much value to the medicolegal expert in estimating age or sex of human remains.
7. Racial differences in eruption of teeth are largely uninvestigated. There appears to be much parallelism between Caucasians and Japanese, only the maxillary canine emerging earlier in Japanese than in Whites. Sex differences in the two racial groups are very similar. African Blacks, on the other hand, may be considerably more precocious dentally than European or American Whites.
8. No universal standards of eruption have been developed for the deciduous teeth.
9. Intensive studies of the "rhesus" monkey indicate that serial records on teeth can be used in the future to assign a birthdate to a war orphan or a foundling with no birth certificate.
10. In using teeth as age indicators one should never place reliance on only one or two teeth, if this can be avoided, since the one or two teeth observed may happen to be the least representative members of the entire dentition.
11. The timing of the baby's first teeth may be of value in settling certain disputes of contested paternity; very early teething is to be expected if the period of pregnancy is unusually long, and *vice versa*.

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Criteria of Individuality in the Teeth*

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Identification involves the determination of the relationship of given evidence, known or unknown, to other evidence. Re-

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lating details of fact and structure may range from a microscopic detail to an entire dentition. Hence, a critical evaluation of the individuality and significance of the various possible elements of evidence in the dentition is a necessity.

It is not sufficient to say that evidences match or that cause and effect are apparent. Validity and individuality must be demonstrated not only to ourselves but also to the critical eyes of those who are to use the evidence presented (1). It behooves us to survey and evaluate these entities of the dentition which can be put to such use.

Teeth are not indestructible, but certainly they are more stable than any of the other tissues of the body. In many instances of violence, destruction, or deterioration, the only evidence remaining are teeth or parts of them. By their nature, in manner of formation and structure and in their relative permanence, they record and retain the history of their development and of the incidents to which they have been subjected during their existence.

Many of the dental features which are considered usable as evidence are common to many individuals of practically every population. Here, as in other similar circumstances, the statistical treatment of the occurrences determines their significance. Frequencies of occurrence of tooth characters are available for a large number of populations and groups. Cultural patterns are known to exert influences on frequencies. These considerations weight the evidence. When such are applied to events, characteristics, measurements and other information which may be gleaned from the teeth, the improbabilities of repetition of the combination in some cases is pyramided to astronomical levels.

Certain identification problems are restricted to age, to inherited features, to matching of similar markings, and so on. Others require an analysis of all the available information that can be obtained from a dentition. These materials can be divided into seven general categories. Although there is some overlapping, the distinctions can be made as follows:

1. Anatomical components (specific units of form and structure).

2. Genetic factors (inherited variations and expressions).
3. Incidents recorded during development (high fevers, interference in metabolism, radiation).
4. Physiological processes (timing and sequence of loss and emergence of the teeth).
5. Markings or alterations.
   a. Fillings and restorations.
   b. Injuries.
   c. Deliberate decoration or mutilation of the teeth.
6. Evidence of aging.
7. Effects of environment and of use (pathology, caries, pyorrhea, nutrition, wear).

A brief elaboration of these categories will serve to give a basis for determining their relevance and individuality. Certain of these are covered in detail by other participants in this symposium.

1. *Anatomical components* include cusps, crowns, roots, patterns, their size, color and other macro- and microscopic characterizations as they ordinarily appear in the general population. Almost all major and minor populations have been studied to determine frequency differences in tooth characters and units. In some instances these vary significantly, whereas in others there is no great difference. Familial trends in character are noted as well, and frequently are of considerable importance. Some tooth attributes such as particular cusps or groove-cusp patterns have a range from zero to one hundred per cent representation in differing populations. They are basic architectural entities of the unit involved and of a long ancestral history in the hominids. They are not accidental occurrences and therefore have dependable individuality. The shovel-shape of incisor teeth, the molar patterns, root formations, and Carabelli's cusp are examples of these.

2. *Genetic factors* are of the utmost importance in discussing individuality of teeth. There are several specific points in this category which need to be stressed. In the human dentition it is almost always the rule that genetically induced features are bilateral. This does not mean, on the other hand,

that all bilateral characteristics or units are necessarily genetic in origin. Effects of environmental incidents such as nutritional disturbances or the process of birth are bilaterally recorded. This does not include such things as anomalous cusps, most supernumerary teeth, and other similar occurrences resulting from developmental incidents. Particular areas of some teeth are quite variable and usually show dissimilarity between the two sides. For example, the distal marginal ridges of premolars, the distal portion of molar occlusal surfaces and the lingual surfaces of upper incisors may, but generally do not, show identical markings or ridges bilaterally. These are a sort of residue area where the cells and their enamel product "bunch up" so to speak, with little orderliness.

One group of genetically produced dental traits that appears unilaterally or bilaterally is the secondary type of character. These include modified or reduced form and size or complete absence (peg or barrel shaped incisors, diminutive teeth, absent cusps as indicated in particular occlusal surface patterns and complete absence of one or more of the variable-type teeth). This kind of dental characteristic has been shown to occur in varying frequencies among different populations. Inheritance patterns have also been demonstrated for these reduced forms. The trait is manifested primarily in the so-called "variable" teeth and not in the "stable" ones unless the variable member of the involved tooth group also shows the modification.

This latter reference to "variable" and "stable" teeth is one point from among several important fundamentals of tooth form concepts (Dahlberg (4)). These give considerable substance to interpretive values of teeth in identification. Many features are common to several teeth in the dentition. Within each of the four tooth-groups that make up the four quadrants there exists a hierarchy wherein certain of the tooth characteristics are manifested in a regularly ordered gradation of size or expression. That is, a given cusp which is found in each of a series of teeth in a tooth-group will be found to be large in one, less large in its immediate neigh-

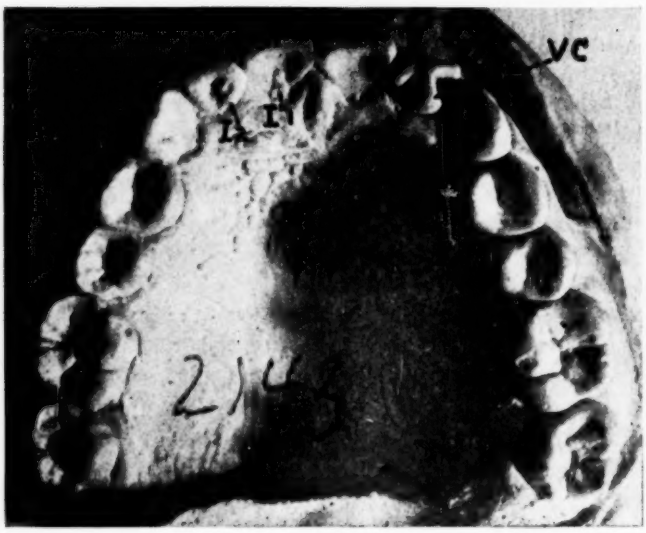

Fig. 1—Occlusal view of an upper dentition. The lingual surfaces of the incisor teeth do not show the markings to be bilateral. I_1, Central incisor; I_2, Lateral incisor; VC, Variable lingual cingulum.

bor, and still smaller in the next tooth beyond. Where frequencies per tooth are known for such characters in a population a statistical predictability is possible for the description probabilities of adjacent unknown teeth on the basis of the evidence exhibited in a single tooth. As an example, among one group of American Indians the protostylid is found on lower molar teeth in high frequency. It is found in white populations only rarely. In the Indian population the cusp, when occurring in a sequence in a dentition, is smallest in the third molar and increasingly larger down through the second and first permanent molars and on to the second deciduous molar, which is part of the same series. If a second permanent molar were found having this cusp, it would be expected that from the same person the two first permanent molars, the two second deciduous molars, and the second molar from the other side of the jaw would also

Fig. 2—Buccal view of lower right second (M_2) and first molars (M_1). The protostylid is shown to be more marked on M_1 than on M_2.

show the same structure. The frequencies of the cusp in this group is 67% for the lower second deciduous molar, 30% for the lower first permanent molar, 6% for the lower second permanent molar, and 0.5% for the third molars. Hence, in the instance just mentioned, the probability of finding it in the third molar would be 1:12. The fact that this cusp, like most other dental characters, is not exclusive to or excluded from any population of mankind brings up the question of the statistical probability of duplicating the event (13, 14). This will be discussed later. Suffice it to say at this point that genetic factors do contribute to the individuality and significance in interpretive values of the teeth.

3. *Incidents recorded during development.* (Although in a strict sense the categories of evidence presented here could be reduced in number so that physiological processes would include others as subdivisions, the purpose here is to catalogue for convenience and to emphasize the processes and techniques available and in use.)

High fevers, excessive radiation, and certain metabolic disturbances are known to disturb developing cells or tissues and leave marks which are retained as long as the tooth or teeth

exist. These can be recognized and their significance can sometimes be read long after the incidents themselves are forgotten. Bilateral registrations at varying positions on different teeth reflect the stage of development of the dentition at the time of the event. These facts are so fundamental in the cell activity that they are unquestionably individual and valid evidence. Occasionally, more than one event is involved, such as the malnutrition and radiation of the atomic bomb casualties. Here, superimposition of effects occurred so that they could not be distinguished.

4. *Physiological processes* in this fourth category include the timing and sequence of loss and emergence of the teeth, growth, development, and maturation of occlusion.

Although there is a wide range of sequences and timing for the emergence of the permanent teeth in every population, the statistical mean for these events differ from group to group. The American Indian and some other populations are found to have the lower first molar erupt first in the majority of cases (12), whereas reports on white children of New York by Hellman (11), New Zealanders by Leslie (15), and English school children by Clements et al. (3) show a marked trend to have the lower central incisor as the first member of the permanent dentition. There are other differences, some more meaningful than others. The American Indian begins the replacement process later and finishes earlier than most other groups.

These points could be important in identification. The timing and sequences seem to follow familial patterns as well.

The process of occlusal maturation differs among cultural groups. In adjusting to the occlusal and proximal requirements of opposing and adjacent teeth, certain facets and points of occlusal contact become apparent on the teeth. These are highly individual tell-tale marks.

The incremental lines, neonatal line infancy ring, and such developmental rhythmic recordings in enamel and dentin are certainly most individual (Massler and Schour (16)).

5. *Marking or alterations* may be by accident or by design. Accidental markings on the teeth are generally the effects of

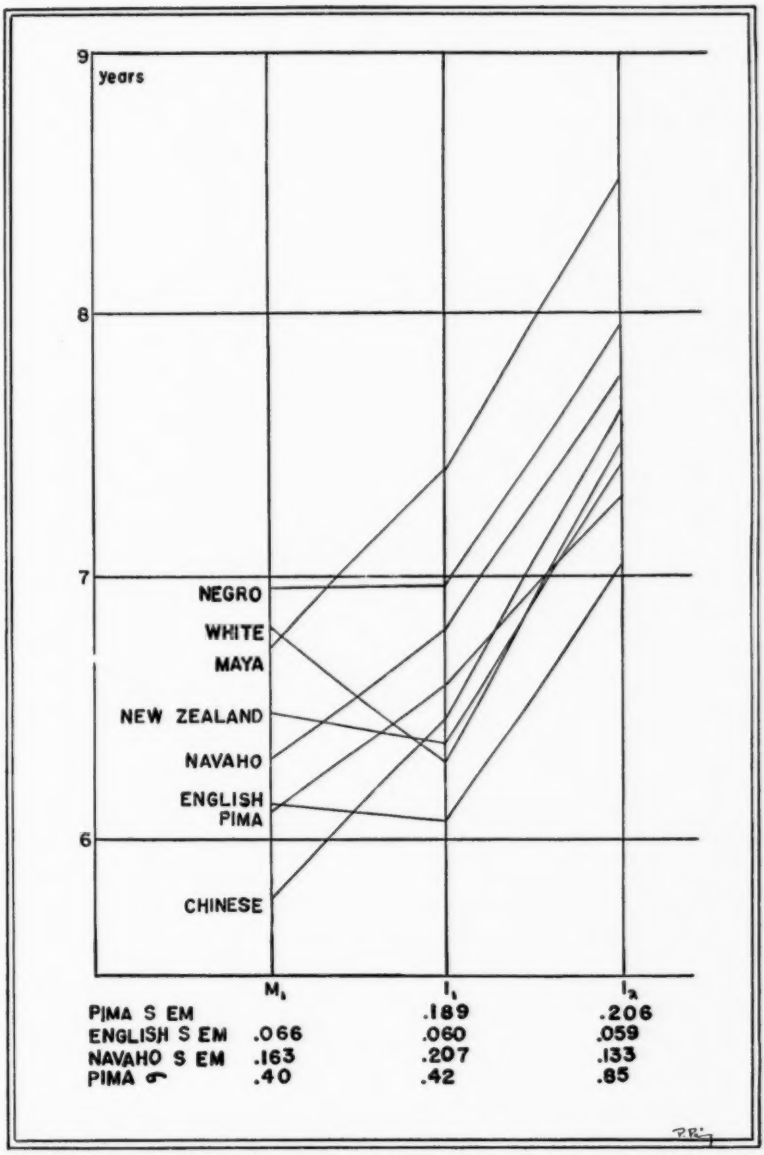

Chart I. Chart shows the mean eruption time and sequence of the lower permanent first molars (M_1), central incisors (I_1) and the lateral incisors (I_2) for eight populations.

habits, of restorative appliances, or of a blow. Fractures are less prone to occur in teeth which are larger and more resistant to shocks by virtue of particular anatomical characteristics. According to Professor Kei Enoki of Tokyo (7), Mongoloid peoples have a much lower frequency of fracture of incisor teeth than do other peoples. This is attributed to the excessively heavy lateral ridges found on the lingual surfaces of their incisors (shovel-shaped incisors) (Figure 1). Pedigree studies of this feature have shown a familial trend towards heaviness, moderate form, or absence.

Tobacco and beetle-nut chewers, pipe and bobby pin holders, toothpick users, and others in occupations requiring use of the teeth (Eskimos, Indians) are examples of those who impose distinctive markings on the teeth.

Deliberate markings include necessary restoration of diseased or missing parts, decoration, and mutilation. Fillings, dentures, and the various types of dental appliances are high in the order of individuality. They not only reflect events in the history of the dentition, but also give an increase in the improbability of duplication of the same circumstances by virtue of the number of types and manners of correction possible in different dental practitioners' hands. Cultural aspects have heavy impacts in this phase of the discussion. Social pressures in certain communities give the presence or absence of these dental restorations varying significance. For example, some rural areas have no strong community feeling about individuals appearing without front teeth whereas others have inter-individual standards which would make appearance in public without an upper front tooth a very embarrassing experience.

Only a limited number of individuals in the United States seek excessive decorative effects in the teeth. These are generally limited to gold shell crowns or large gold fillings in the anterior teeth and only rarely with the placement of a precious stone, such as a diamond, in the crown. On the other hand, beauty in the accepted sense of regular alignment, unmarred tooth surfaces and pleasant natural tooth appearance is frequently sought after, particularly in the

urban areas. The restorations here referred to are the all-porcelain fixed bridge as contrasted to a removable type of bridge and the very highly esthetic porcelain jacket crown.

Mutilation of the teeth is not practiced in this country and would be encountered only in the case of the unusual transient from one of the areas where it is commonly done (South Pacific Islands, certain tribes of Africa) (Drennan (5), Hambly (10)).

6. *Aging evidences* may be many, both on the surface and on the interior of a tooth. Some signs of age can be duplicated by other causes. Although secondary dentin and the condition of the cementum have definite implications in age determinations, these same conditions can be produced by heavy abrasion and attrition and by pathological conditions which are not necessarily too severe. On the other hand, the surface studies and techniques of Dr. David Scott (19), are not likely to be in error. Evidences of antiquated dental procedures and certain types of fillings found in a tooth, may be helpful in dating (Gustafson (9)).

7. *Environment and use* of the teeth tend to influence dentitions to develop the occlusal relationships one way or another. Cultural backgrounds again are highly relevant. Early heavy chewing habits involving coarse foods and the use of tough mutton bones as pacifiers produce an entirely different occlusion and arch form than do refined cereals and strained food diets and a plastic rattle. Degrees of wear are not dependent on age, but on use. Some American Indian populations of pre-Columbian and even one of post-Columbian times showed excessive wear resulting in pulp exposures in most of the populations in the early-twenty age groups (Goldstein (8), Snow (20)).

The degrees of wear have been classified by Brocca (2) and modified by Moorrees (18) to give the significant steps from (0) no wear, (1) slight wear of the cusps, (2) cusps greatly worn, (3) cusps completely worn, hollow indentations left by dentin exposures, to (4) one half to nearly complete loss of the crown.

In reviewing these categories, there can be no question but that enough is known about the possible points of evidence to give them a high rank of individuality.

Discussion

In the latter part of the last century, attempts were made to catalogue human measurements for identification purposes. Bertillonage (6) as this system was called, finally gave way to the more accurate method of fingerprinting. Fingerprinting is not likely to be displaced by a dental-classifying technique. On the other hand, in government services where there are great possibilities of identification problems arising, there is no question but that advantage should be taken of dental records routinely made, and that a system should be set up which is based on the stable and relatively indestructible dental tissues and restorations. In the general population individual cases involving dental evidence certainly will be well served. However, the problem is a slightly different one.

Many of the items discussed in the various categories of dental evidence can be duplicated time and again in most populations. It is only when these evidences are in combination in multiple that they become completely acceptable as indisputable evidence by everyone's standards. There is always the question concerning the point at which converging probabilities from circumstantial evidence becomes certainty. In the courts, this is reached when the evidence is beyond reasonable doubt. It need not be beyond all doubt for that is considered to be an impossibility.

Thus in computing the probabilities of duplication of a set of evidences the effort must be to present a figure about which there would be little doubt. With all the dental features possible to include there is generally little difficulty in doing this either in the affirmative or in the negative as the case may indicate. The proportion should be at least a ratio of 1:number of the available population.

In determining the probabilities, care must be taken that different events used in the combinations have separate backgrounds of causation. For example, 0.5% is the frequency

with which the mesial surface of a lower left canine is found to be involved with a defect in a given population. This is a proportion of one to two hundred. The frequency for the same surface of the lower right canine is also 0.5%, again one to two hundred. The frequency of missing lateral incisors is 2%, or one in fifty. In determining the probabilities of duplication, the combination of the lateral incisor event with the right canine defect is legitimate and would be 1:10,000. However, the defect on the right and left canines is likely to have the same or closely related cause. Hence, they are not acceptable for combination. Finding one or both canines involved would not alter the probabilities from one in two hundred unless positive evidence of different causes is presented. All the evidences must be scrutinized in this manner (17).

Statistics are available for many of the evidences discussed in this paper. In some instances, special quests may have to be made in specialized literature.

Summary

Identification involves the determination of the relationship of given evidence, known or unknown, to other evidence. Relating details of fact and structure may range from a microscopic detail to an entire dentition. Hence, a critical evaluation of the individuality and significance of the various possible elements of evidence in the dentition is a necessity.

It is not sufficient to say that evidences match or that cause and effect are apparent. Validity and individuality must be demonstrated not only to ourselves but also to the critical eyes of those who are to use the evidence presented. Therefore, it behooves us to survey and evaluate these entities of the dentition which can be put to such use.

Teeth are not indestructible, but certainly they are more stable than any of the other tissues of the body. In many instances of violence, destruction, or deterioration, the only evidences remaining are teeth or parts of them. By their nature, in manner of formation and structure and in their relative permanence, they record and retain the history of

their development and of the incidents to which they have been subjected during their existence.

Many of the dental features which are considered useable as evidence are common to many individuals of practically every population. Here, as in other similar circumstances, the statistical treatment of the occurrences determines their significance. Frequency of occurrence of tooth characters is available for a large number of populations and groups. Cultural patterns are known to exert influences on frequencies.

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Racial Traits in the Human Teeth*

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How much can one tell about the race of an individual from the examination of his teeth? Six years ago the answer would have been optimistic (Lasker (14) 1950). Many of the anatomical variations of the dentition are largely determined by heredity and could be expected to vary in frequency from group to group. Furthermore, teeth are the hardest structures in the human body, a property helpful in the historical study of race as well as in forensic odontology.

The extravagant hopes for the use of dental features as "hallmarks of race" have not been fulfilled. In a recent publication Klatsky (10) (1956) lists the incidence of supernumerary teeth, congenitally missing teeth, peg teeth and

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impacted teeth in skulls of 25 geographic groups of man; the frequency of these anomalies displayed by this compilation is strikingly uniform throughout the world. Nevertheless, if the teeth are studied in greater detail, some racial differences will be seen and one can make a realistic appraisal of their usefulness for racial diagnosis.

The necessity of attention to details of tooth morphology prevents us from taking up at this time the intriguing problems of racial differences in features of the jaws. Suffice it to say that bone is a more labile tissue than dental enamel, and that form of the dental arches and occlusion, palatine torus, diastemata, etc., are therefore subject to change under environmental stresses throughout life whereas some inherited racial traits of the teeth are relatively fixed from early in life if they are not destroyed by subsequent attrition or decay.

The most unsatisfactory aspect of racial odontology is the dearth of comparative studies;[1] few investigators have attempted direct comparisons of samples of 2 or more racial groups. We are a little better off in respect to monographs concerning single populations as, for instance, Campbell's (2) study of the teeth of Australian aboriginals (1925), Shaw's (21) on the Bantus of Africa (1931), Drennan's (4) on Bushmen (1929) and Nelson's (17) studies of the teeth of American Indians of Pecos Pueblo (1938). More recently we have had monographs on the teeth of East Greenland Eskimos (Pedersen (18) 1949), Norwegian Lapps (Selmer-Olsen (19) 1949), Texas Indians (Goldstein (5) 1948), Bushmen (Kiernberger (9) 1955) and Aleuts (Moorrees (16) 1957). But isolated studies are of only little forensic interest because many of the data were obtained by methods of measuring or rating which do not permit direct comparisons. Furthermore, there remain many gaps in coverage; for instance, there is no good morphological study of the teeth of the American Negro.

[1] K. Hanihara (Studies on the deciduous dentition of the Japanese and Japanese-American hybrids, Zinruigaku Zassi, 1954, 63:168–185; 1955, 64: 63–82 and 1956, 64:95–116), in a still incomplete study being published in the Journal of the Anthropological Society of Nippon, abstracts in English the results of his systematic comparisons of the dental casts of some 134 Japanese children and 65 children of Japanese mothers and American white fathers and 33 children of Japanese mothers and American Negro fathers.

Some worthwhile work has been done recently. A few years ago, Tratman (22) (1950), who practiced dentistry in Singapore for many years, described the differences he observed between the teeth of the various peoples there. Much of Tratman's data had been lost during the war, but he was able to supplement his impressions with examples, at least, and in some instances with statistical compilations. His generalizations concerning the comparison of Mongoloids (primarily Malays and Southern Chinese) with Indo-Europeans (Asiatic Indians and Europeans) constitute the most useful comparative racial description now available. Last year, Dr. A. A. Dahlberg (3) (1956) and his associates and students at the Zoller Laboratory of Dental Anthropology at the University of Chicago prepared a series of dental casts showing a wide range of dental variations. These casts have been mounted systematically in 17 plaques which can be used for direct comparison with other casts or skulls and, if reference is made to these casts, a degree of standardization can be achieved.

Relying heavily on the sources mentioned above and supplementing them with other published data, we shall try to extend our discussion to a general description of some dental differences between the major groups of mankind.

There is some objection to use of measurements of teeth as racial traits. In the first place, available anthropometric surveys on different races are usually the work of different researchers, therefore small interpersonal differences in definition of landmarks or technique of measurement may be misinterpreted as racial. Secondly, the decision whether to measure or reject teeth with a certain amount of occlusal and interproximal attrition is arbitrary and likely to vary from one investigator to another. And thirdly, sex differences in tooth size are considerable and, if sex is not known, size of teeth is a poor index of race.

Despite these limitations, one can say that, in general, there are large-toothed and small-toothed races. Thus, as may be seen in the comparative odontometric study of Selmer-Olsen (19) (1949), Australians, Melanesians, American Indians and Eskimos have large teeth, with long wide crowns; Lapps and

Bushmen are small people with small teeth, and Europeans and American Whites vary in tooth-crown size from one place to another. Ainos (Koya (12) 1937) and American Negroes have teeth with large average crown dimensions.

The relative as well as the absolute size of various teeth may also give some clue to race. The size of lower molars in most peoples decreases from first to third, but in Australians the second lower molar tends to be the longest (Drennan (4) 1929). Eskimos have large molars by comparison with average-sized premolars and anterior teeth (Pedersen (18) 1949). In Whites, the upper lateral incisor tends to be much smaller than the central; the difference in size between the two is usually not so great in Mongoloids (Pedersen (18) 1949). First premolars and especially third molars are somewhat more likely to vary between groups, while in respect to race as well as to individuals, the first molar is more constant in size. Selmer-Olsen's compilation (19) (1949) shows an apparent tendency for the roots of teeth to be deep in Australians, deep by contrast with the low crowns in Bushmen, but shallow compared with the high crowns in Lapps, and both absolutely and relatively shallow in Japanese.

To speak of a dental trait as "racial" merely implies that it occurs in higher frequency in one race than in another; it is very unlikely that a certain feature will be found exclusively in a given race. Morphological characteristics, especially certain anomalies and the fine details of dental anatomy are more likely to reveal such racial differences than are over-all projected measurements of maximum length or breadth. The morphology of individual teeth is by no means independent; marked development of the shovel-shaped trait in all four upper incisors with related features in canines and lower incisors probably tells one little more about the race of the person from whom these teeth have come than could be learned from a single incisor tooth.

It has been claimed that dental numerical variation (congenital increase or decrease in number of teeth) will not only throw light on the phylogeny of the dentition and the evolutionary status of man but will also show specific racial distributions (Pedersen (18) 1949). There are, however, three

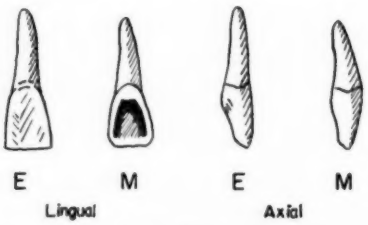
difficulties in the use of presently available knowledge of numerical variation for the purpose of racial diagnosis: 1. Data on dental numerical anomalies are still lacking for many races; 2. Where numerical variations have been examined clinically the findings are rarely confirmed by radiologic examination; and 3. In older persons it is sometimes difficult to know if a certain tooth has been lost or was congenitally absent.

The deciduous dentition will be mentioned only briefly. The time or order of change of dentition, although differing between individuals, appears to be similar in the various races. Other traits in deciduous teeth have been little studied in respect to race. Although Pedersen (18) (1949), Tratman (23) (1950) and Dahlberg (3) (1956) have described some morphological characteristics of the crowns of deciduous teeth, these are found also in the permanent teeth of the same racial group. No work seems to have been done on the odontometry of the deciduous dentition as such. Because of variations in their absorption, the condition of the roots of the deciduous teeth can supply little useful information.

We shall first consider the racial traits of each tooth group and shall then briefly summarize the most salient features of the teeth of persons of particular races.

Maxillary Incisors

The most prominent racial variation of the upper incisors is the absence or varying degree of development of marginal ridges. In some Mongoloids these are so well developed that they consist of dentin as well as enamel and may be visible on the labial as well as the lingual surface. On the labial aspect one sees two longitudinal grooves; on the lingual aspect the ridges mark off a depressed area, and the tooth may be described as shovel-shaped. Hrdlicka (7, 8) (1920, 1921) noted a high frequency of shovel-shaped incisors in Chinese, Mongols, Eskimos and American Indians. The same characteristic may be seen in Negroes (Hrdlicka (7) 1920, and Shaw (21) 1931) and Whites (Syrians: Seltzer (20) 1936; and Finns: Koski and Hautala (11) 1952) and is occasionally lacking in Mongoloids.



MAXILLARY CENTRAL INCISORS

Fig. 1—Maxillary central incisors of Europeans (E) and Mongoloids (M): Lingual view shows chisel-form (E), and development of the lateral ridges and cingulum giving a shovel form (M); mesial and distal ends of the incisal edge are beveled in M. The axial view shows longer root and less angulation of the crown in E than in M. (After Tratman.)

One of us (Lasker), in a survey of 355 American Whites has found 45% of 642 maxillary central incisors and nearly 50% of lateral incisors were shovel-shaped; but in only one case was the trait marked, and in only 14% of cases was it rated as moderately well-developed. Lasker (13) (1945) previously found moderate or pronounced shovel-shaped incisors in 85% of 269 Chinese. These figures for Chinese and American Whites are similar to Hrdlicka's (7) (1920) original findings on these racial groups: full development of the trait is characteristic of Mongoloids and rare in Whites.

The development of the mesial and distal marginal ridges in Mongoloids is more evident in upper lateral than upper central incisors. The same is probably true of other races, however. Dahlberg (3) (1956) has noticed some upper lateral incisors of American Indians with such marked development of the cingulum and the marginal ridges that the tooth appears barrel-shaped. Kiernberger (9) (1955) reports one such case from South Africa. Perhaps this is similar to the conical upper lateral incisor with deep lingual pit which Tratman (23) (1950) describes in East Asians.

An additional median longitudinal ridge on the lingual surface has not been systematically studied in respect to race, nor has the frequency and degree of development of the cingulum, tuberculum dentale and lingual pit. These traits may be least characteristic of the so-called "white" racial stock.

Fig. 2—Maxillary lateral incisors, lingual view. The European tooth (E) is chisel-shaped and has a longer root than the shovel-shaped Mongoloid tooth (M), the distal (left) end of the incisal edge is beveled in M. (After Tratman.)

Reduced and conical upper lateral incisors are more common in Caucasoids than in other peoples (Shaw (21) 1931, and Pedersen (18) 1949). This would seem to account for the smaller average width of upper lateral incisor which is reported for all groups of Europeans when compared with groups of other races (Selmer-Olsen (19) 1949). Total absence of upper lateral incisor also is generally considered to be more common in Europeans (Pedersen (18) 1949).

In respect to the shape of the incisors, Tratman (23) (1950) reports that the greatest width of the crown is farther from the occlusal edge in Mongoloids than in Indo-Europeans. He relates this to a rounding of the incisal edge (and beveling of its distal end in upper lateral incisor) of Mongoloids. He also noticed that the angle between the long axes of the root and that of the crown is nearly 180° in Indo-Europeans but somewhat less in Mongoloids. Such an angle would provide a more vertical occlusion between prodontic teeth such as are common in Mongoloids but Tratman's "Indo-Europeans" are mostly Asiatic Indians, also a prognathic people so this difference need have no functional significance.

The incisor roots are generally short in Mongoloids (Tratman (23) 1950); Miyabara (15) 1916). Pedersen (18) (1949) says the shortening is progressive with age and ascribes it to resorption in connection with a powerful bite in such peoples as Eskimos, but Selmer-Olsen (19) (1949) points out that in Lapps, who also have a powerful bite, the upper incisor roots are relatively short but the lower incisor roots are long. Tratman (23) (1950) adds that the root is short in

Mongoloids even in the absence of increased secondary cementum or evidence of occlusal wear.

Mandibular Incisors

The mandibular incisors sometimes show accentuation of the lingual marginal ridge, but this trait is regularly less marked than the marginal ridges of the upper incisors. Tratman (23) (1950) refers to a rounding of the incisal edge and shortness of the roots of lower incisors in Mongoloids, but most authors find no racial differentias in these teeth. Congenital lack of lower incisors, however, appears to be relatively more frequent in Chinese, Japanese, Eskimos and American Indians (see Pedersen (18) 1949, and Goldstein (5) 1948) than in non-Mongoloids.

Canines

The canines are not very distinctive teeth. Maxillary canines sometimes show prominence of the lateral margin in individuals (hence in racial groups) in whom the incisors are shovel-shaped. Other racial characteristics of the upper incisors are present in the canine, but in less marked degree. The cingulum is probably better developed in non-Europeans than in Europeans (Kiernberger (9) 1955; Pedersen (18) 1949), but a true lingual cusp is rare in all groups. The canine may extend beyond the other teeth in Africans (Kiernberger (9) 1955; Shaw (21) 1931), but the Bushman lower canines are very small and gracile teeth. The canines are occasionally large in Negroes (Shaw (21) 1931) and Australians (Campbell (2) 1925) but tend to be small in Mongoloids, at least by comparison with other teeth (Tratman (23) 1950). The roots are typically long and pointed in Europeans; variant forms, flattened or even divided at the tip, occur more frequently in other groups (Shaw (21) 1931).

Premolars

In the Mongoloid, the presence of an occlusal enamel pearl is apparently more common than in other premolars. The trait occurs in either maxillary or mandibular first or second

premolars (Pedersen (18) 1949; Tratman (23) 1950). In all these teeth the single rooted form is more frequent in Mongoloids than in Whites (Pedersen (18) 1949; Tratman (23) 1950); on the other hand, a tendency to root division and two- and three-rooted forms are more common in the Bantu than in other races that have been studied (Shaw (21) 1931).

MAXILLARY SECOND PREMOLAR

Fig. 3—Maxillary second premolar of a Mongoloid showing occlusal enamel pearl. (After Tratman.)

A feature occasionally present in the mandibular second premolar is a marked compression in the bucco-lingual dimension with a compensatory increase in the mesio-distal diameter of the crown. According to Dahlberg (3) (1956) this is seen only in members of the white race; therefore, in view of Dahlberg's wide experience with the teeth of American Indians and other groups, this trait, when present, should be a valuable criterion of race.

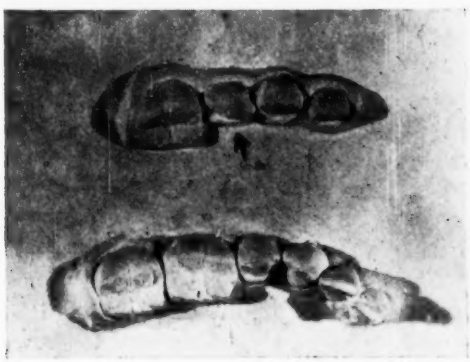


Fig. 4—Buccolingually compressed mandibular second premolar of White (above) compared with tooth of more usual proportions (below). Casts courtesy of A. A. Dahlberg.

Maxillary Molars

The main fissures of maxillary molars are said to extend farther toward the tooth margins in Mongoloids than in Indo-Europeans (Tratman (23) 1950). A wrinkled appearance of the enamel is sometimes seen in unworn Mongoloid molars. When the trait occurs it is most often in the third molar and ordinarily does not affect the first (Pedersen (18) 1949). Furthermore, according to Kiernberger (9) (1955), wrinkling of molar crowns is a characteristic feature of Bushmen and Hottentots.

The usual number of cusps of upper molar teeth is four. In Australian Aborigines and Bushmen there are said always to be four in the first two maxillary molars and in three-quarters of the third (Campbell (2) 1925; Drennan (4) 1929). In Bushmen the first two maxillary molars have four cusps but the third molar usually has only three—sometimes with an additional cusplet. In Eskimos (Pedersen (18) 1949), Aleuts (Moorrees (16) 1957), Texas Indians (Goldstein (5) 1948), Pecos Pueblo Indians (Hooton (6) 1930), Bantus (Shaw (21) 1931) and indeed all peoples, the first maxillary molar is virtually always four-cusped, and the third molar is usually three-cusped but may have six, five, four, two or only one cusp.

In all these variations it is usually the distolingual cusp, the hypocone, which varies in size or is totally lacking. Kiernberger (9) (1955) says that in upper second molars of Bushmen this cusp is sometimes divided into two to five cusplets.

The cusp counts do not include Carabelli's tubercle which may appear on the mesio-lingual aspect of the first maxillary molar. When present on the first molar it may occasionally be seen on the second and even, though rarely, on the third molar. The variable expression of the trait and the occasional pit at the site may have caused different students to rate the trait quite differently; and, in the absence of uniform standards, comparisons should be avoided. One of us (Lasker) has examined 582 maxillary first molars of American Whites and found Carabelli's cusp to be present in some degree in 37%. An even higher incidence is reported by some other workers in other white races. Pedersen (1949) found that Carabelli's tubercle is extremely rare or practically absent in

pure Greenland Eskimos but frequent in Eskimos with white admixture. Pedersen (18) (1949) also quotes work of other authors who have found a very low incidence in Chinese but one a little higher in Japanese. Tratman (23) (1950) concludes that Carabelli's cusp is much more frequent in his Indo-European group and more variable in the Mongoloids whom he has studied. Shaw (21) (1931) saw only a few cases in his Bantu series.

Fig. 5—Carabelli's cusp on mesial part of lingual aspect of maxillary teeth: in second deciduous molar but not first permanent molar (above); in both these teeth (middle); and in first and second permanent molars (below). Casts courtesy of A. A. Dahlberg.

Tratman (23) (1950) has called attention to the greater frequency of prolongation of the enamel onto or rather between the roots of Mongoloids, sometimes fusing under the crown.

More often it extends between the two buccal roots, and sometimes there is a detached "pearl." Pedersen (18) (1949) has observed the same difference between Eskimos and Danes.

In Mongoloids the molar roots show a tendency to be fused and are shorter, especially compared with the body (or neck) height, and less splayed (Pedersen (18) (1949); Tratman (23) 1950). Abnormal divergence of roots is also lacking in Bushmen (Drennan (4) 1929). There is little if any tendency to difference in the number of roots of the maxillary molars of various groups. A single rooted maxillary third molar is frequently found in all races.

In the molar teeth of Mongoloids the pulp cavity is often exceptionally wide and deep. The term for this characteristic, *taurodontism*, has been applied to a large rectangular pulp chamber in a tooth with completely fused roots. Tratman (23) (1950) notes, however, that in Mongoloids the upper first molar may display an hour-glass form with partial root fusion and enlarged pulp cavity. Furthermore, in the upper third molar, and also sometimes the second, an enlarged pulp cavity is more often associated with a pyramidal fused root. Whereas Tratman (23) (1950), looking at taurodontism in Asiatic Mongoloids, considers the pyramidal form less diagnostic, Shaw (21) (1931), in describing taurodontism in mixed races of South Africa, considers the depth of the pulp chamber as primary and the breadth (substitution of a "body" for the "neck" of the tooth) as a necessary concomitant. In any case, the more extreme types and degrees are rare or absent in mod-

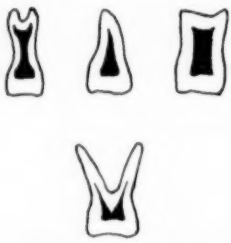


Fig. 6—Taurodont maxillary molars (above) showing hour-glass, pyramidal and rectangular enlargements of the pulp cavity compared with cynodont tooth form (below).

ern Europeans. Europeans more often have long, widely splayed roots which are not uncommonly crooked (Pedersen (18) 1949). Congenital lack of the upper third molars may occur in all races. It is probably most common in Mongoloids and is rarest in Australians.

Mandibular Molars

As in the upper molars the grooves in the lower molars of Mongoloids tend to be deeper and extend farther toward the margins (Tratman (23) 1950). The grooves may separate three buccal cusps and two lingual cusps so as to form a "Y," or they may cross in a "+" form. The distinction in groove pattern is dependent on the size of the distolingual cusp rather than directly on the presence of a fifth distal cusp (Dahlberg (3) 1956). However, the "Y" form more often goes with five cusps, the "+" form with four cusps. Goldstein (5) (1948) found both more five-cusped teeth and a higher incidence of "Y" patterns in the lower molars of Eskimos than of Texas Indians, for instance. The cusp number in the lower first molar is almost always five in all races. According to Tratman (23) (1950), the fifth (distobuccal) cusp of Mongoloids is often further subdivided into a larger buccal and smaller lingual portion. In lower second molars, however, there is a high proportion of reduction to four cusps—especially in Whites (see Pedersen (18) 1949) but also in some United States Indians (Nelson (17) 1938; Goldstein (5) 1948) and even in Australian Aborigines (Campbell (2) 1925). Among Bushmen (Drennan (4) 1929), Bantus (Shaw (21) 1931), Eskimos (Pedersen (18) 1949), and Aleuts (Moorrees (16) 1957) the majority of lower second molars have five cusps. The number of cusps on the lower third molar is more variable. The majority of these teeth have five cusps in Bushmen (Drennan (4) 1929), Eskimos (Goldstein (5) 1948; Pedersen (18) 1949), Aleuts (Moorrees (16) 1957) and Australians (Campbell (2) 1925) but not in Bantus. Bantus (Shaw (21) 1931) and some American Indians (Goldstein (5) 1948; Nelson (17) 1938), like Europeans (see Pedersen (18) 1949), have more third molars with a reduced number of cusps.

Like the maxillary molars, the mandibular ones usually decrease in size from first to third. Variations probably have

little value in diagnosis of race, although small second and especially third molars may be rarer in Australians (Campbell (2) 1925) and Bantus (Shaw (21) 1931).

The racial distribution of the paramolar tubercle or protostylid on the mesiobuccal surface of one or more mandibular molars has been less studied than that of Carabelli's tubercle of upper molars. Like Carabelli's tubercle, counts of the protostylid are complicated by various accounts given of small forms and pit or groove forms. Pedersen (18) (1949) concludes that the paramolar tubercle is common in Eskimos and in colored races when compared with Europeans. Dahlberg (3) (1956) reports a tendency for greater display in Mongoloids. Moorrees (16) (1957) found no cases in Aleuts, how-

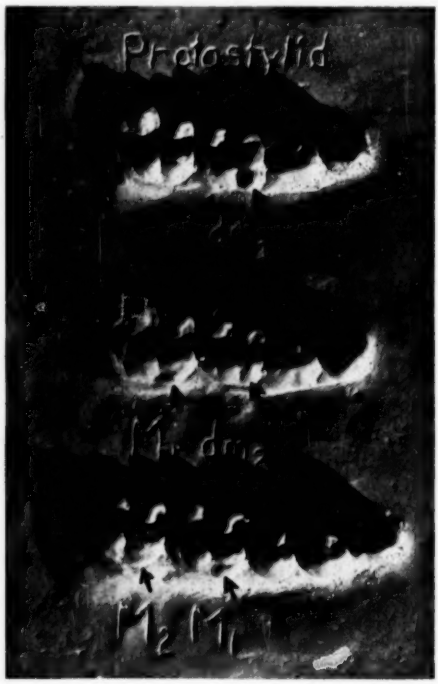


Fig. 7—Protostylid on mesial part of buccal aspect of mandibular molar teeth: in second deciduous molar but not first permanent molar (above); in both these teeth (middle); and in first and slightly in second permanent molars (below). Casts courtesy of A. A. Dahlberg.

ever. Tratman (23) (1950) mentions several other features of upper molars as also shown in the lower ones. He says that the crown is more bulbous and tapering toward the cemento-enamel junction in Mongoloids, that enamel extensions are more common, and that the roots are shorter, straighter and less splayed than in Indo-Europeans.

An extra distolingual root on the lower first or third molar but rarely if ever on the lower second molar is a helpful character in racial diagnosis. Tratman (22) (1938) found no cases in Europeans, only one case in 582 such teeth from Asiatic Indians, but 8% in 1,349 extracted lower first molars of Southern Chinese, 11% of 527 Malaysian lower first molars and a slightly lower frequency in lower third molars of these Mongoloid peoples. Pedersen (18) (1949) also reported the distolingual root of lower molars at least ten times more frequent in Eskimos than in Europeans. Such a root was not present in any of Shaw's series of Bantus (21) (1931).

Taurodontism occurs in mandibular as well as maxillary molars, but to a lesser extent (Pedersen (18) 1949). The pyramidal form may occur in various races; but the hour glass type and a greater frequency of the pyramidal type are said to be more characteristic of Mongoloids.

Fourth Molars

Unlike other supernumerary teeth, the distomolar appears more frequently in certain peoples than in others. Both maxillary and mandibular fourth molars are said to be more frequent in Bushmen and Negroes than in Whites or Mongoloids (Kiernberger (9) 1955); and, in Australians, Birdsell (1) (1950) has found one area of the country with an incidence of fourth molars of nearly 10%. Had x-rays been used and especially if retro-molar alveolar foveae had been counted, as is sometimes done on skulls, the frequency might have been higher.

Deciduous Teeth

A systematic analysis of racial traits of the deciduous dentition does not seem warranted. Even less concrete evidence is available, and in general the characteristics are similar to those of the permanent dentition.

Deciduous incisors are sometimes shovel-shaped. This is not as pronounced as in permanent maxillary incisors and, when present, may be considered predictive of the latter. Fusion of the deciduous lower lateral with the central incisor or canine is sometimes noted. It may be more frequent in non-Europeans, but the racial distribution of the trait is poorly documented.

Carabelli's cusp is frequent in the deciduous upper second molar, presumably in the same racial groups that show the trait in permanent molars. Likewise the protostylid is frequent in deciduous lower second molars in those groups with frequent protostylids of the permanent dentition. In both instances, however, the second deciduous molars may have the trait whether or not it is present in the corresponding first permanent molars of the same individual. Tratman (23) (1950) notes that in lower second deciduous molars the "Y" pattern is more common in Mongoloids, and that they may show two buccal pits, occasional enamel extensions and greater body length. He found 1% of these teeth had an extra distolingual root whereas no cases were observed in Indians or Eurasians. Among over 3,000 lower first deciduous molars the third root occurred in only two, those of a Chinese and a Malay. The ratio of anterior to posterior bucco-lingual diameter of lower first deciduous molar may also vary with race (Dahlberg (3) 1956), but we know of no comparative data.

Discussion

So far we have not discussed dental arch form, rotation of teeth, type of occlusion and other features of the supporting structures and jaws. Our chief reason for omitting these is the complex and little understood relationship of environmental factors that may influence racial genetic features of this kind. True, some authors have called attention to the crowding of teeth in the offspring of interracial marriages, and they consider this to be a specific "racial" reaction. However, crowded teeth are common in some inbred groups, they vary with environment (Lasker (13) 1945) and small teeth in large jaws are rarer than large teeth in small jaws,

although both should be equally frequent in persons of biracial origin if genetic reassortment were the explanation.

We have here limited our consideration to differences in respect to traits of individual teeth between individuals of different race. Such statements about major racial groups are not entirely justifiable. "Races" are abstractions whereas racial traits actually occur in varying frequencies among the members of smaller breeding populations. In one instance Birdsell (1) (1950) has demonstrated an extraordinarily high incidence of fourth molars for a comparatively small population of a few tribes in Southwestern Australia. In another case Tratman (13) (1950) reports that in Tioman, a small island in the Malay States, 8 out of 103 individuals examined manifest congenital absence of lower incisors, a very rare trait in most groups and a rare condition even in other Mongoloids. Similarly, Selmer-Olsen (19) (1949) found sharp differences in tooth form between subgroups of Lapps, and Moorrees (16) (1957) thinks the teeth of Eastern and Western Aleuts may differ. Perhaps some of the differences between different studies of Europeans or of American Indians are due to differentiation between contiguous small groups. Such local evolution, the widening circles of intermarriage, and the large measure of interindividual variability in any group will probably continue to restrict the usefulness for forensic purposes of racial criteria of the teeth. In this respect teeth are hardly more—or less—reliable than hair, skin, blood or bony remains. Modern communication and the lack of barriers to intermating limit the value for forensic purposes of any kind of racial classification today. Nevertheless, a more systematic sampling of the World's populations following a standard procedure, such as is now possible with the use of the Zoller Laboratory Casts, should make for an increased knowledge of racial odontology. Even with present knowledge, a study of the teeth may, in some instances, prove helpful in racial evaluation of forensic cases.

Summary

There are marked differences in frequency of various features between different racial groups. In general, Europeans

show the highest frequencies of chisel-shaped incisors, Carabelli's cusps, reduced number of molar cusps, and cynodont molars with bent and splayed roots. Mongoloids show high frequency and marked degree of shovel-shaped teeth, enamel extensions onto the roots, enamel pearls, taurodont molars, wrinkled molar crowns, fused roots and extra distolingual roots of mandibular molars. Negro teeth are not well known, but Negroes, Australians and Melanesians show least reduction in size and number of the molar teeth. American Indians and Eskimos are essentially like Asiatic Mongoloids in dental traits; Asiatic Indians are like Europeans; Bushmen and Hottentots show some similarities and differences from each of the foregoing groups.

Superimposed on the differences between major racial groups, however, there are numerous differences between individuals and between local populations. Furthermore, the lack of distinct racial boundaries, large number of intermediate groups and increased rate of intermating, limit the value for forensic purposes of dental or any other kind of race classification.

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The Genetics of the Human Dentition*

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My approach to this subject will be somewhat oblique. The title of this paper should perhaps be limited to: "The Genetics of the Human Dentition—A Preliminary Exploration of Potentialities." It is somewhat doubtful if there yet exists a field of systematic research into the heredity of the dentition.

I shall attempt to outline my approach to the study of the human dentition, the central problems which motivate this study, some of the results, and an interpretation of these results as they pertain to the problems. The application of some of the results to the field of forensic medicine will then be indicated.

The literature is amply populated with numerous kinds of studies of the human dentition. They may be sorted roughly under the following descriptive categories:

1) Comprehensive descriptions of the dental features of a skeletal series.

2) Twin studies of such subjects as pathological entities, occlusal types, incidences and topologies of caries, anomalies, and so forth.

3) Concentrated studies of single entities such as shovel-shaped incisors or Bolk's paramolar tubercle as they are manifested morphologically and incidence-wise over various populations.

As single outstanding examples of each category I might mention the work of Pedersen (1) on the Greenland Eskimo dentition, the twin studies of Korkhaus (2), and the papers of Hrdlicka (3) on shovel-shaped incisors (4).

At the very core of the anthropologist's interests in human anatomy lies the theme of the nature and pathway of man's evolution. To aid him in his scrutiny and analysis of anatom-

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ical variations the anthropologist borrows techniques and methods from biology, mathematics, and chemistry. Very often in the process of observing and interpreting differential frequencies of occurrence of anatomical variants, the anthropologist comes up with data and ideas which might be called by-products in that they have applications peripheral or in addition to the aggrandizement of evolutionary knowledge.

In this paper I should like to present to you a by-product of my study of morphological variations in the human dentition.

Of the many types of approaches that have been taken to the subject of the dentition, it seems to me that a very important one has been neglected. There has been lacking, regrettably, a systematic, thorough descriptive analysis of the morphological variations of the crown surfaces of each of the components of the human dentition. At the University of Arizona we made a start in this direction, having completed a rather intensive examination of the mandibular first and second premolars and the maxillary first premolar. We shall confine our attention at this time to the mandibular first premolar; note some of the anatomical variations, their distributions in different human populations, the evidence for their heritability and interdependence, and the potentialities for the applicability of this information to problems in forensic medicine.

The mandibular first premolar is generally described as having a large buccal and a small lingual cusp, the two being united by a median ridge. In 1953, Furr and I (5) indicated that this is neither a description that fits generally nor does it necessarily apply to the majority of the first premolars. Furthermore it tended to cover up the fact that the crown surface of the premolar can and does vary in a great many ways.

These variations can be described (in the case of dental casts) under 16 categories. For example a study of hundreds of dental casts has indicated that while a buccal cusp is always present and clearly observable, there may be one, two, or even three lingual cusps. The number of lingual cusps is not constant but shows marked populational differences. To determine the frequencies of the various aspects of this and

other premolar traits, a sample of ethnic groups living in Arizona was drawn and dental casts were obtained. The sample consisted of 200 Whites, 30 Negroes, 50 Papagos, 30 White Mountain Apache, 130 Yaqui, and 30 Chinese (6).

It was found that the Negro dentition differed significantly from that of all the other groups in having a preponderance of mandibular first premolars with 2 lingual cusps. In addition, this tooth in Negroes bears with fairly high occurrence three lingual cusps. In all the Mongoloid groups tested, there were no occurrences of three lingual cusps and the one-cusp lingual pattern had a frequency of 67–87%. With respect to this trait, there were no significant differences among the four Mongoloid groups, nor were the Caucasoids distinguishable as a group from the Papago, Apache, or Chinese. The Caucasoids and Yaqui had significantly different frequencies for the distribution of the number of lingual cusps (7).

Scrutiny of large numbers of premolar teeth showed a clear-cut difference in the disposition of the main lingual cusp (called by me the "deuteroconid" and by deJonge the "cuspis oralis"). In some cases the cusp seems fused to the occlusal surface of the buccal cusp ("protoconid") and takes on more the appearance of a lingual tubercle or "protostylid." In others the cusp is quite independent and has a palpable apex. A study of the distribution of these two aspects of a trait we might term "deuteroconid disposition," reveals notable differences among the sample groups we have mentioned. Here the Papago and Apache are similar, differing, in turn, from all other groups. They are distinguished by having approximately equal numbers of fused and independent deuteroconids. All other groups show, on the other hand, a great preponderance of independent lingual cusps. The Negroes are particularly noteworthy in this respect, 90% of the casts showing independent lingual cusps. The Yaqui and Caucasoid distributions are quite similar.

All observers have noted the median ridge (protoconid occlusal ridge) that proceeds lingually down the occlusal surface of the protoconid from the apex to the base or to the adjoining lingual cusp. They have generally failed, however, to call attention to the fact that sometimes this ridge is straight and uninterrupted throughout its course while at other times

it bifurcates and sends an accessory ridge down either side of the occlusal surface of the protoconid. While all population samples studied showed both types of ridges there were significant differences in the relative frequencies. In this trait the Caucasoids and Negroes were similar, about 55% of the teeth manifesting the unbifurcated type of protoconid ridge. All Mongoloid samples revealed precisely the opposite distribution, ranging from 61% to 77% frequency of the bifurcated protoconid ridge.

Let us take one more example from the total list of 16 traits. We have observed that there may be a single ridge (an unbifurcated protoconid ridge) on the occlusal surface of the protoconid, or there may be two (when the main trotoconid ridge is bifurcated). In addition to these, there frequently are occlusal ridges adjacent to, and morphologically independent of, the main ridge. A total of four ridges (including the main ridge and its bifurcating branch) has been observed in all the sample populations. The number of ridges is distributed differently in these populations. Two ridges is the characteristic feature of Caucasoid mandibular first premolars, with a frequency of 46%. All the Mongoloid groups are characterized by a high frequency of three-ridge premolars. In Chinese 50% of the lower first premolars have three occlusal protoconid ridges. The Papago premolars are noteworthy in the high percentage (32%) having four occlusal ridges, while the Caucasoid premolars show an almost equally high frequency of one-ridged protoconid surfaces.

Other traits include: the number of grooves appearing on the lingual surface of the crown (there may be none, one, or two); the presence or absence of mesial or distal ridges on the margins of the protoconid or buccal cusp; the presence or absence of mesial or distal ridges on the lingual half of the tooth; the position of the main lingual cusp (or deuteroconid) with respect to the apex of the protoconid (the lingual cusp may be mesial, median, or distal); the relative size of the protoconid itself (it may be classified as slight or prominent).

Of the 16 traits, 10 were selected at random for purposes of studying sample distributions. We would expect to find significant differences in the frequency distributions of the aspects of these traits between the Caucasoids and the Ne-

groes, between the Negroes and each of the Mongoloid groups, and between the Caucasoids and each of the Mongoloid groups. This is precisely what we find. Six of the ten traits show significantly different distributions for Caucasoids and Negroes. All four of the Mongoloid groups differ in at least 4 traits and some in 7 traits from both Negroes and Caucasoids.

On the other hand, if we are anthropologists of the "classic" school, we expect to find relatively fewer differences among the four Mongoloid groups, by virtue of the fact that they *are* members of the same "stock" or sub-species of *Homo sapiens*. It is therefore interesting to note that there are almost as many significant differences occurring between any two members of the Mongoloid group as are found between Caucasoids and Negroes. There is no discernible pattern of traits which falls into the significant category. There are, for example, more differences between Yaqui and Papago than between Papago and Negro, or between Chinese and Caucasoids! A trait which is similarly distributed for both Caucasoids and Negroes, may clearly differentiate Papagos and Apache!

In explanation of these populational phenomena, we might suggest that to treat the hundreds of populations in Asia and the Americas under the old familiar rubric "Mongoloid" is perhaps to lose sight of some very important principles of biological evolution. Many of these populations, such as the Papago and Apache, have remained relatively isolated for hundreds and perhaps thousands of years. There is no doubt that the Papago and the Apache have maintained breeding isolation with respect to each other for many more years than have the American Whites and Negroes. We know that isolation inevitably results in diverging gene frequencies and increasingly differentiated gene pools. These genetic differences in turn would naturally be reflected in differences in the frequencies of some of those phenotypic traits which they are instrumental in bringing about.

Our speculations raise the question: Are these morphologic traits of the mandibular first premolar really heritable? Can they be used as yardsticks of the genetic affinities and dif-

ferences of populations? For our answer we turn briefly to twin studies.

Since the traits under discussion are bilateral, we must first agree upon some system for judging concordance and discordance between two members of a pair. If we consider as concordance the case where *all four* mandibular premolars in a pair of individuals agree as to aspect of a particular trait, then we have obtained the following results. In a sample of 12 identical twin pairs, 14 fraternal twin pairs, and 8 pairs of unrelated individuals, all selected from a Caucasoid population, the mean numbers of concordances among these three groups of pairs in 16 traits were computed. For identical twin pairs the mean number of concordances was 9.4; for fraternal twin pairs it was 6.0; and for unrelated pairs it was 5.1. A "t" test showed the difference between identical and fraternal twin pairs to be highly significant. On the other hand there was no significant difference in the number of concordances between fraternal and unrelated pairs.

Another way of demonstrating the heritability of these dental traits is on the basis of average number of discordances per twin pair, considering a discordance to be present when both teeth on one individual differ from both on the other member of the pair. This might be termed "total discordance" for the trait. Reckoning this way, it was found that for identical pairs the average number of total discordances in 16 traits per pair was 0.67; for fraternal pairs, 2.93; and for unrelated pairs, 3.62. Again a "t" test showed the difference between fraternal and identical twin pairs to be highly significant.

If we can now accept the thesis that these mandibular first premolar traits are heritable, we must still raise the question of the interdependence or non-interdependence of the 16 traits. Is each an independent variable or are some functions of others? Since there are 16 traits we can make 120 pair comparisons. The method is to prepare tables presenting the number of concomitant occurrences for each aspect of the two traits being compared. Application of the Chi Square test will determine whether the pattern of concomitancy indicates a high or low probability of independence of variation.

Let us take for example the 55 comparisons of pairs of traits, each with only 2 aspects. In other words, there are 55 2 by 2 tables, each with one degree of freedom. How should the Chi Squares of these 55 tables be distributed if the distribution is a random one? For presumably, if the traits are not interdependent, their degrees of concomitancy will be distributed at random. We may construct a table of observed and expected frequency distribution of Chi Squares having one degree of freedom with unequal class intervals. A Chi Square test of this distribution (having 13 degrees of freedom) gives a Chi Square value of 12.14 with a P value greater than .40. Therefore there is no evidence that two-aspect traits are not distributed randomly with regard to each other.

The same failure to prove interdependence is met when we compare pairs of traits having more than two aspects. We can then assume that these traits are actually independent variables. In other words they are inherited as discrete units at least with reference to other mandibular first premolar traits.

I have indicated, to sum up, that 16 morphological structures can be demonstrated on the crowns of the mandibular first premolars. Each structure or trait may vary in two or more ways. Each variate is inherited, and each trait is inherited independently of any other. I must caution, however, that these conclusions are based upon relatively small samples and should be tested further.

Since these traits are of common occurrence and their various aspects are almost all fairly frequent in occurrence in all populations studied, and since they are heritable and vary independently, they become of great importance not only for the study of population breeding units and population differentiation, but also might well form the basis for a new system of positive individual identification of both skeletal material, such as war dead, and unidentified living persons.

Let us take, for example, the Apache Indian population from which my sample was drawn. Let us presume, indeed, that the sample is truly representative of one entire Apache population, such as, say, the San Carlos Apache. The frequencies of no lingual grooves, one lingual groove, and two lingual grooves are: 75%, 14%, and 11% respectively. In

other words, the chance of an Apache individual, picked at random, having a mandibular first premolar with two lingual grooves is only .11. Similarly the chance that a randomly picked Apache would have a single rather than a bifurcated protoconid ridge is .30. And of having no mesial protoconid marginal ridge is .39. The chance, therefore, of a random selection of an Apache with all three characteristics is simply the product of the separate probabilities or .013—that is, slightly more than 1 chance in 100!

If we utilize all 16 traits it is obvious that the chances of any particular combination may become exceedingly small, on the order of one chance in millions. On the other hand if each trait aspect had a 50-50 chance of occurring, the chance of all 16 occurring in a specific combination would be one in 65,536.

There is not time to discuss the difficult problems of bilateral symmetry and asymmetry, which complicate the probability picture and throw up formidable obstacles to analysis of the genetic mechanisms involved. I can only say that there is a distinct tendency toward bilateral symmetry in these premolar traits but that the average frequency of bilateral asymmetry is from 20% to 30%. Bilateral asymmetry of even this relatively small amount will tremendously lower the probabilities of any two individuals having four identical premolars with respect to the 16 traits mentioned.

Summary

No systematic work has been done toward a genetic analysis of common inherited morphological structures of the human dentition. Such an analysis must be preceded by careful anatomical description and study of populational variations. The full potentialities of the human dentition for studies both on macro- and micro-evolutionary levels have not yet been fully appreciated. A by-product of such studies will be a new method of identification of paramount importance in the identification of skeletal material as well as in many other aspects of forensic medicine.

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Palatoprint, Physioprint, and Roentgenographic Cephalometry, as New Methods in Human Identification*

(Preliminary Report)

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In the field of human identification, either on the living or on the skeletal remains, many techniques have been utilized, the most widely used being fingerprints. However, the taking of fingerprints may not be feasible and, hence, other approaches are needed. Besides, in many legal cases, more than one type of evidence may be required to establish identity within a reasonable doubt. It is with these aspects of the problem in mind that the following new methods are presented.

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Generally speaking, the techniques of human identification may be classified in two major categories:

1. *Comparative group:* In this category are techniques based upon a previous record, classified and kept in a central file, to which given remains or documents may be referred. The matching sets of records constitute a proof of identity; to this category belong fingerprints, photographs, dental records, etc. Among the methods here presented, the palatoprint, the physioprint, and one aspect of roentgenographic cephalometry are part of this first group.

Identification achieved by techniques of this category present a high degree of reliability and accuracy. They are aimed at the identification of a particular individual.

2. *Reconstructive group:* In this category there is no previous record to which given remains or documents may be compared or to which they can be referred. The basic aim of these techniques is to deduce from the remains the maximum information pertaining to the person: age, sex, race, stature, body build, and a record of illness and accident. In other words, we seek to establish as many criteria of individuality as are possible and feasible.

In this second group belongs the study of bones, teeth, blood group, hair, and so on. Among the methods presented here, one aspect of roentgenographic cephalometry, combined with the physioprint, belongs to this group. At best, the methods included in this group suggest possibilities and probabilities but cannot achieve certainty in the details of identification of *an individual.*

As far as their application is concerned, some of these methods are more suitable for the living individual (identification of criminals), others for skeletal remains.

The palatoprint and the physioprint may be used for the identification of the living or the dead whose facial and palatal soft tissue is not mutilated or otherwise rendered inadequate for detailed study.

Roentgenographic cephalometry may be used for indentification of the dead where the skull is preserved.

I. Palatoprint (Fig. 1)

The palatoprint is the impression of the soft tissues covering the hard palate transposed on a flat sheet. The print shows the map of the rugae, papillae, and midline ridge. The arrangements of these papillae is individual. On one hundred palatoprints taken from serial dental casts, I have been able to ascertain that: 1) no two palates are alike in their configuration; 2) the palatoprint does not change during the period of growth. The last statement is limited by the fact that the

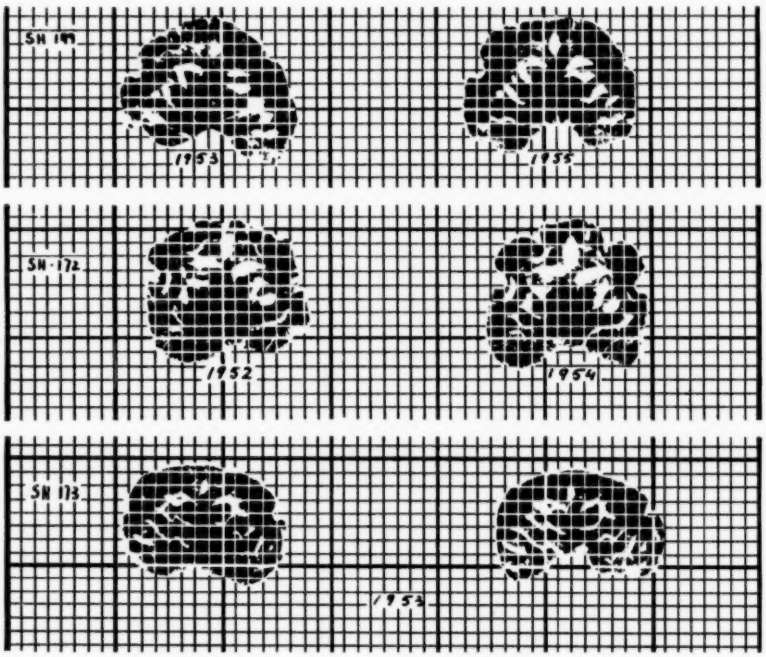

Fig. 1. PALATOPRINTS of the same individuals taken from dental models. Clay was used here instead of bubble gum. They show that, over a period of years, the configuration of the papillae has not changed for all practical purposes. Notice also the diversity of their pattern.

age span covered is only a few years. In addition, the possibility of changes during late adulthood, subsequent to extraction or the wear of full dentures, should be investigated.

a) *Technique:* On the living I found that the simplest way to take the palatal impression was to give the subject bubble

gum to chew; with a plastic or small wooden spoon, press the gum against the palate. Take it off, roll it smoothly against an ink-pad, and pass the inked-gum-impression on millimetric-paper (Fig. 1). The cost per impression is one cent (.01).

b) *Classification:* A preliminary attempt has been made to classify the palatoprints according to:

1) The symmetry of the papillae.
2) The number of the papillae.
3) The shape of the papi lae.

This classification tested on one hundred cases permitted me to identify the person without great difficulty. However, on a very large number of subjects, the problem may become more complicated. It is probable that a more elaborate classification will be required, which means the inclusion of more palatal traits.

c) *Application:* The palatoprint may be used exactly as a fingerprint. The method here proposed is rapid, accurate, and inexpensive. Its falsification through surgery is more difficult than in the case of fingerprints. It seems to me advisable to take both of them as a basic record, thus providing cross-check in doubtful cases.

This discussion of the palatoprint should be considered as an initial proposal, subject to more elaborate research.

II. Physioprint (Fig. 2)

The physioprint (analogous to the fingerprint) reproduces the contours of the face at each level of depth. It provides a contour map of the face and, at the same time, gives dimensions. In a synthetic way, it translates on a flat surface the three-dimensional architecture of the face. When the contoural and dimensional pattern is considered, no two faces are alike. The physioprint accentuates the differences not only of the profile but of the whole face, providing a new method of identification. It remains still to be demonstrated how much age, fat, or plastic surgery can alter the physioprint and to what extent. This study is under way and as a first observation it seems that the upper face (orbital, malar and frontal area) is less subject to change than the lower face (naso-oral area).

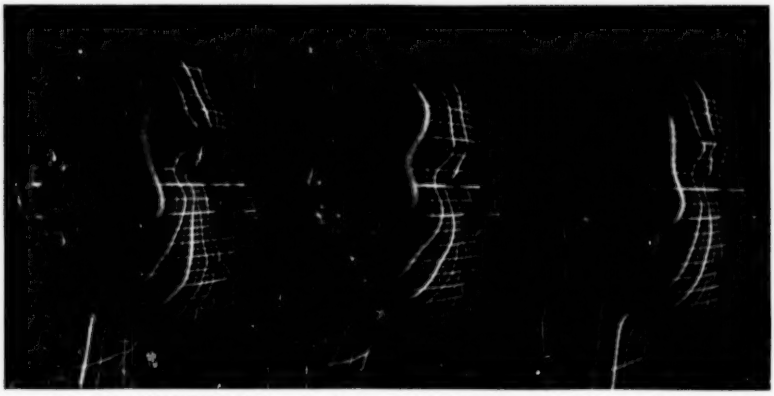

Fig. 2. PHYSIOPRINTS of different individuals taken with a grid composed of white lines. They give sizes as well as proportions of the face. The lines are 5 mm apart. The physioprints have been taken with a Polaroid camera.

a) *Technique:* The Sassouni physiograph consists of a standard slide projector (2 x 2 or 3 x 4). A slide representing a millimetric grid (Fig. 3) is projected onto the face. One

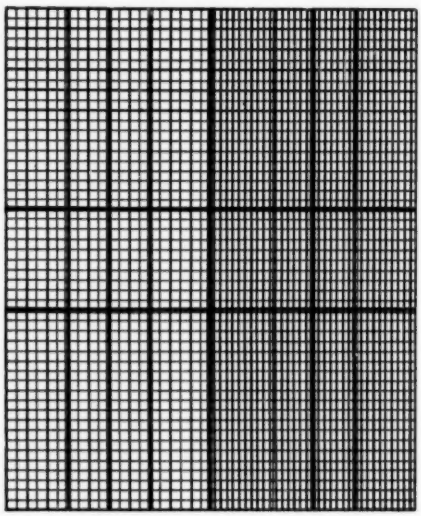

Fig. 3. GRID: On the left the calibration is such that, at 8 feet the squares have 5 mm sides. On the right, the vertical lines are one mm thick and 2 mm apart. These two grids are combined on the same slide to provide two possibilities of physioprints.

heavy horizontal line of the grid represents the Frankfort Horizontal (Orbitale-Tragion); one heavy vertical line of the grid represents the midsagittal plane through nasion.

The subject is seated facing the projector; the head is then oriented so that the vertical line passes through nasion, and the horizontal line through left orbitale and right and left tragia. A headrest insures the immobility of the subject. In this position, at a right angle, the photograph is taken (Fig. 4).

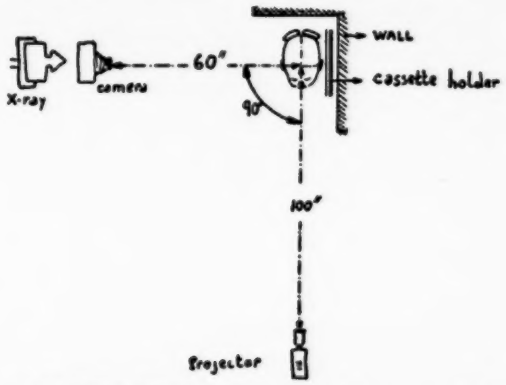

Fig. 4. THE SASSOUNI PHYSIOGRAPH: the camera and the projector are at right angles. They are on the same horizontal level as the Frankfort plane of the subject. Once the patient is positioned, oriented x-ray films can be taken.

The accuracy of this method necessitates the following conditions:

1) The camera and the projector should be oriented at right angles to each other.

2) The camera, the projector, and the Frankfort plane of the subject should be on the same horizontal level.

3) Distortion and magnification are almost completely avoided if the camera is 60″ from the subject and the projector 100″ from the subject.

4) With a 500 watt projector and Tri X films, no other source of light is required.

A Polaroid camera also gives good results with No. 400 film.

Lange and Hertzberg (1) have devised a much more complex apparatus to achieve a similar result.

b) *Classification:* The physioprints can be classified (Fig. 5) and identified. They can also be put on film and superimposed in toto to test the identity of a given subject. The classification gives the best result if areas are considered separately: fronto-orbital, malo-gonial, naso-oral. Elimination and selection should be done, starting from the relatively more stable areas.

Fig. 5. PHYSIOPRINTS taken with a black-line grid. The vertical lines are 1 mm thick and 2 mm apart. They illustrate the diversity of facial patterns on different subjects. These physioprints have been taken with an Exacta at 5 feet from the subject.

c) *Application:* If standardization of this method could be achieved throughout the country and a central master-file built up, the process of identification can be operated exactly as in a fingerprint. The physioprint also has wide applications in orthodontics, in prosthetics, in oral and plastic surgery, in anthropology, and in sculptural reproduction.

In conclusion, physiography is a promising technique. However, for each of its applications, special studies should be done. We are in the process of collecting material (approximately 200 physioprints thus far).

III. Roentgenographic Cephalometry

Roentgenographic cephalometry (3) is the quantitative evaluation of cranio-facial sizes and proportions measured

on tracings of x-ray films of the head. In order to obtain a three-dimensional appraisal, two sets of films are taken for each subject; one lateral which gives the heights and depths, one frontal which gives breadths and heights. On these films, bony and soft tissue landmarks may be defined and located. The accuracy of the measurements depends primarily on the standard orientation of the head, the position of the cassettes, and the source of x-ray. Generally, the films are taken according to the Frankfort Horizontal and the midsagittal plane of the head.

In 1931, Broadbent (2) introduced a cephalometer answering these requirements. It permits taking accurate films with a minimum of intervention by the operator, therefore, minimizing the sources of error. From 1931 on, many studies based on oriented headplates were devised and have contributed to a better insight of head and face (proportions and growth).

To date the most frequent application of roentgenographic cephalometry has been in the field of orthodontics. These studies (3) have gathered a vast amount of quantitative data about the "normal" face, as contrasted with cases presenting dento-facial deformities.

Different types of cephalo-facial analyses have been proposed: angular, linear, proportional or positional.

In the field of human identification, some roentgenographic cephalometric norms may be applied fruitfully.

The Sassouni Analysis (4, 5), being geometrical as opposed to mathematical, proportional as opposed to dimensional, individual as opposed to average, analytic for evaluation, and synthetic for classification, three-dimensional by conception, is particularly suitable for such an application.

The Norms in the Sassouni Analysis:

A. *Lateral film* (4) (Fig. 6)

a) *planes:* trace the supraorbital plane (anterior clinoid to tangent of orbital roof); trace a parallel to it from the lowest border of sella turcica; trace the palatal (ANS-PNS), the occlusal, and mandibular planes. In well-proportioned faces, the four

planes meet at a point O. More often, three of them tend to meet in a focal area O.
The manner in which the fourth plane is divergent constitutes the basis of the facial classification.

b) *arcs:* from O as a center draw four arcs. In a well-proportioned face the *anterior arc* (radius O-Nasion) passes through ANS, tip of the maxillary central incisor and pogonion. The manner in which any of these three points is divergent from this optimum pattern constitutes the classification of the profile.
The *basal arc* drawn from point A downward passes through point B.
The *median arc* from Te (intersection of the anterior border of the temporal fossa with the ethmoidal line) is tangent to the anterior contour of the maxillary first permanent molar.
The *posterior arc* through dorsum sella passes through gonion.
From these arcs it was found that the cranial base length (dorsum sella to nasion) is equal to the mandibular corpus.
The clivo-mandibular angle is equal to the angle formed by the ramal and the supraorbital plane. It is generally close to 90°.
The palatal plane passes through the foramen magnum.

c) *Vertical balance:* anteriorly and posteriorly upper face was found to be equal to lower face in well-proportioned faces. This norm in turn is the basis of the vertical classification: lower face may be larger or smaller than upper face.

d) *Teeth axes:* the angle formed by the lower central incisor with the occlusal plane is equal to the occluso-ramal angle. The angle formed by the lower incisor with the palatal plane is equal to the angle formed by the upper incisor and the occlusal plane. Maxillary first molar and canine form an isoceles triangle with the palatal plane.

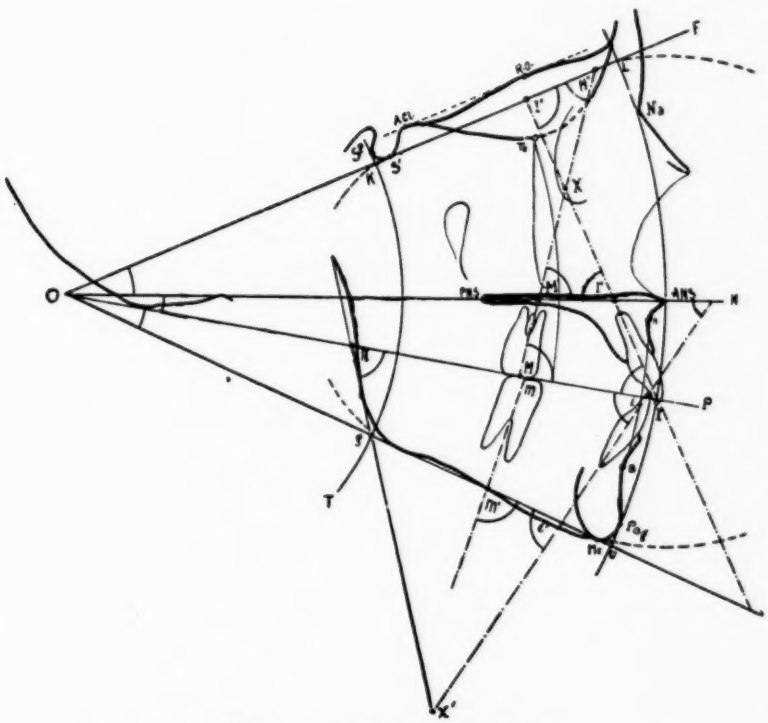

Fig. 6. Analysis of lateral film.

1) Planes:
   A.Cl.-RO = Supraorbital plane
   O-S'-F = parallel to supraorbital plane through S' (lower border of Sella turcica)
   ANS-PNS-O = palatal plane
   P-M-O = occlusal plane
   Me-g-O = mandibular plane

2) Arcs:
   Center = O = intersection of supraorbital, palatal, occlusal and mandibular base planes.
   Anterior arc = L-Na-ANS-I-Pog
   Basal arc = A-B
   Temporal arc = radius O-Te
   Posterior arc = radius O-Sp

3) Teeth axes:
   Upper and lower central incisors
   Upper and lower first molars

B. *Frontal film* (5) (Figs. 7 and 8)

The corpus length (non-projected Go-Pog) is equal to the bigonial diameter. The bigonial diameter is equal to the biorbital (Lo-Lo) diameter. The biorbital diameter is equal to the distance from latero-orbitale to the upper central incisor (contact point). The bilateral position of the maxillary first permanent molar is defined by the line drawn from Lo to Mx (maxillare). In other words, the three-dimensional norms of a face are represented geometrically by four equal equilateral triangles (Fig. 8).

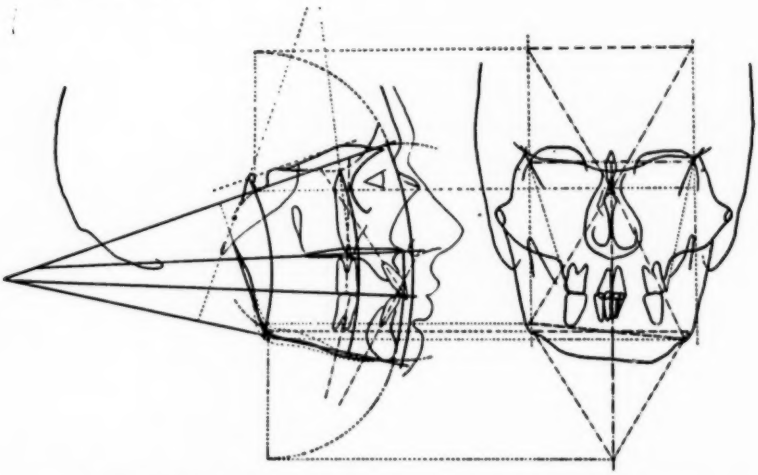

Fig. 7. SASSOUNI'S ANALYSIS: On the tracings of oriented x-ray films, the three-dimensional analysis of the cephalo-facial complex is done according to the norms described in the text.

These norms can be used in both reconstructive or comparative methods for identification purposes.

I. *Reconstructive application:* In this category no previous record exists. Given certain parts of the skull, the aim is to reconstruct the missing parts. The result is always hypothetical. The greatest error occurs in cases presenting large deviations from the norms. But, this cannot be checked.

The case presented in Figures 7 and 8 will be taken as an example. We will suppose that the maxillary teeth and the whole mandible are missing and we will try according to

the norms described above to reconstruct the missing parts. In Figure 9 the dotted lines show the reconstructed parts.

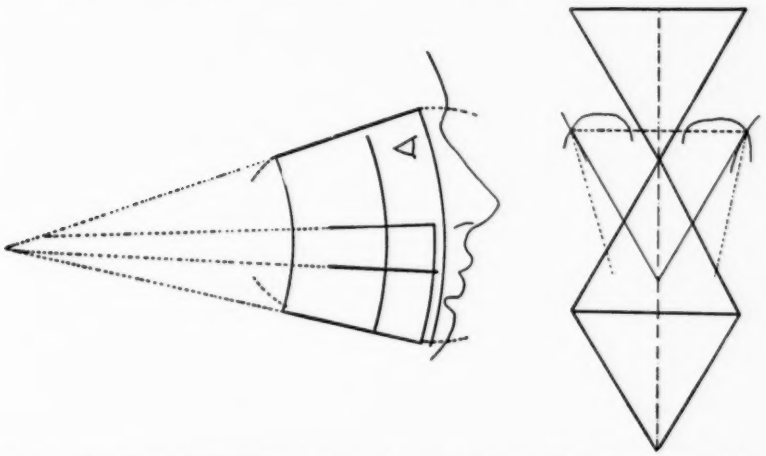

Fig. 8. FACIAL TYPING of the subject shown in Fig. 7. It translates the pattern of the face in three-dimensions.

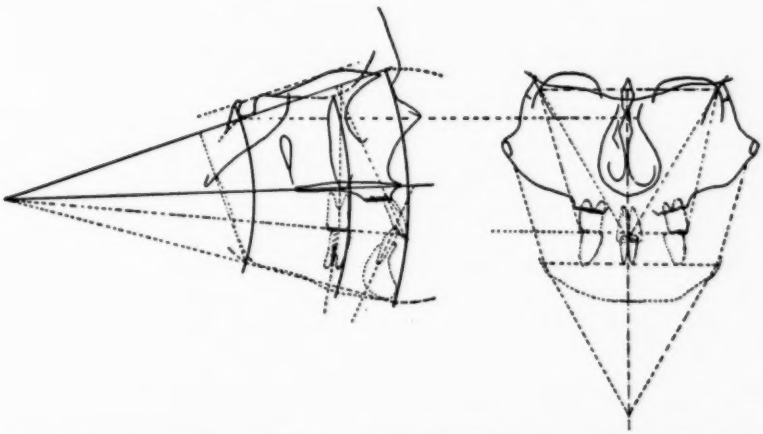

Fig. 9. RECONSTRUCTION OF THE DENTAL ARCHES AND THE MANDIBLE. Same case as in Figs. 7 and 8. In here, the dental arches and the mandible have not been drawn. It was supposed that the only remains found were those of the cranium and the upper face (solid lines). The dotted lines indicate the reconstruction of the missing parts according to the norms of Sassouni Analysis (see in text).

Figure 10 shows the comparison between the true tracing (wide lines) and the reconstructed one (thin lines). This shows the amount of error. Specifically, during the reconstruction, the assymetry of the mandible was not detected, the ramus was drawn a little too short, and the chin more protruding.

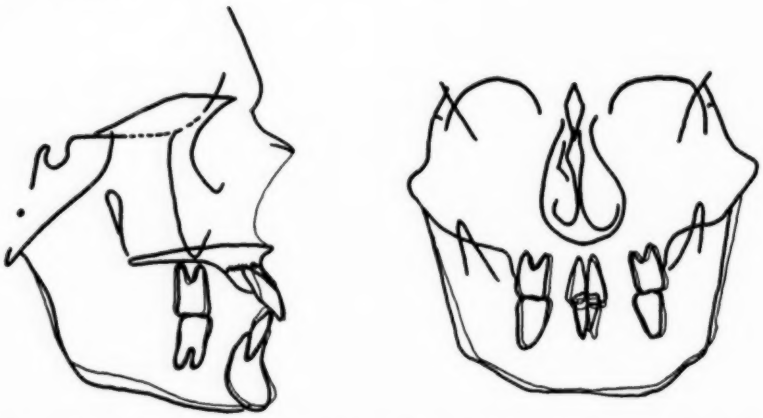

Fig. 10. The reconstructed parts (thin lines) from Fig. 9 have been superimposed on the original tracing of Fig. 7 (thick lines). The differences between the thick and thin lines show the amount of error done in this particular case.

This type of reconstruction has been, this far, possible for the bony structures. The addition of the soft tissue is still questionable. Very few norms actually exist on the correlation between soft tissue and bony structures. The physioprint, being three dimensional, brings new hope toward the solution of this problem.

II. *Comparative application:* This method presupposes that:

1) Oriented films of the entire population have been taken;
2) That these films are filed according to a certain classification (Fig. 10);
3) That a skull-film is taken of a dead and unidentified person;

4) That the corresponding film in the master file can be found through an identical classification.

This analysis lends itself to such an application. Work is actually under progress toward such a solution.

Summary

Three new methods in human identification are presented: palatoprint, physioprint, and roentgenographic cephalometry.

Identification may be achieved either by *comparing* the remains of the deceased to a previous record (fingerprint) or by *reconstructing* the person on the basis of certain norms.

1. *The palatoprint* method is based on the fact that no two palates are alike in every detail.

The diversity of the papillae permits their classification. An inexpensive method is described to transfer the palatal impression to a sheet of paper. Its use for identification purposes is in the same direction as in the fingerprint: a previous record is needed.

2. *The physioprint* is the photograph of the face in which a millimetric grid delineates the surface of the skin at each level of depth. The only instrument required is a standard projector. The physioprint gives the pattern of the face in toto. The arrangement of the contour lines is unique for each face. They provide a basis for a classification of the facial pattern. Identification is made by comparing to a previous record.

3. *Roentgenographic cephalometry* is the assessment of oriented x-ray films of the head, one lateral and one frontal. They provide sizes and proportions in three-dimensions.

The norms of the Sassouni Analysis are described. A reconstruction of the dental arches and the mandible is demonstrated, and, as a test, compared to the original tracing. A classification is proposed, so that identification may be made by comparison with a previous record.

The methods described are promising because of their simplicity and accuracy. However, this should be considered as a preliminary report, subject to further research.

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To the Gamble Brothers, photographers, my thanks for their enthusiastic and unselfish cooperation which was greatly instrumental in the solution of many technical problems.

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The Determination of Barbiturate After Putrefaction

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Evidence of the ability of the barbiturates to withstand cadaveric putrefaction has not been satisfactorily documented. In medicolegal investigations, this problem frequently arises, as does the question of detection of barbiturates in embalmed bodies or in tissue which has been fixed in formalin and stored in the laboratory for a long period of time.

In 1942, Barbieri-Palmieri (1) killed dogs with barbital and phenobarbital, buried them, and at varying intervals exhumed the bodies. It is not possible to interpret his report, however, since the non-specific cobalt color reaction was used for quantitation—or, in some instances, merely detection—of the barbiturates. Also, rather large amounts of tissue were extracted, and no levels were obtained prior to burial.

By combining ultraviolet spectrophotometry with paper chromatography, the advantages of sensitivity and specificity are now appreciated. Such means are widely used by toxicologists to facilitate the appraisal of those cases involving the toxic ingestion of the barbiturates.

This report presents the results of a systematic study using both these methods where liver from a barbiturate death was analyzed immediately after autopsy, and then treated as follows:

(1) Allowed to putrefy in air at 27° C.
(2) Immersed in formalin at 27° C.
(3) Immersed in embalming fluid at 27° C.

At certain periods of time thereafter, appropriate specimens were analyzed for barbiturates.

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Procedure

A tungstic acid filtrate of homogenized liver is prepared. Ten grams of liver are homogenized in a Waring Blender with 50 ml. of warm water. The homogenate is transferred to an Erlenmeyer flask with the aid of 35 ml. of water. Then 10 ml. of 20% H_2SO_4 are added followed by 5 ml. of 50% sodium tungstate solution. After shaking, the filtrate (an average of 80 ml. is easily obtained by suction) was extracted with two 25 ml. portions of chloroform. When emulsions form, separation is easily achieved by centrifuging. The procedure from this point is the same as that of Walker, Fisher and McHugh (2). Six ml. of 0.05 N NaOH are used for the alkaline extraction of the combined chloroform extracts, and the final solution is adjusted to pH 9.5 for spectrophotometry by the addition of 0.2 M boric acid solution.

After the basic and acidic ultraviolet spectra are recorded and calculations made, the acid solution is extracted with ether and a paper chromatographic study is undertaken (3). The amount of barbiturate centered at its particular Rf zone is determined, and the configuration of the basic and acidic spectra of the materials, which might be found located at other zones on the sheet, are noted and evaluated by systematic elution of the entire sheet section by section.

Pentobarbital was added to 10 gram portions of normal homogenated fresh liver to produce levels of 1.0, 2.8, 4.7 and 9.4 mg. per 100 grams of liver. Following the tungstate procedure outlined, the levels obtained after spectrophotometry were 1.3, 2.9, 4.2 and 8.5 mg. of pentobarbital per 100 grams of liver.

Studies have shown that if liver is omitted, the same amounts of pentobarbital added directly to the tungstate mixture as for liver above, and the same procedure followed, 95% of the pentobarbital is recovered; correction is not necessary to compensate for the loss of barbiturate on protein as when tissue or blood are used. Subsequent paper chromatography of the ether extracts of the acid solutions after spectrophotometric quantitation resulted in a 99% recovery of the pentobarbital (eluted from the Rf 0.73 zone) which was actually available for application to the paper.

We were fortunate to obtain a case suitable for this study, and obtained blood and liver from an adult female who died after suicidal ingestion of 3.5 grams of pentobarbital sodium. The pentobarbital level in blood was 2.3 mg.% (2). The concentration in the liver was 9.2 mg. pentobarbital per 100 grams of liver (Fig. 1). The barbiturate extracted from blood and liver was identified as being pentobarbital by a method employing paper chromatography (3) and differential treatment with reagents (4).

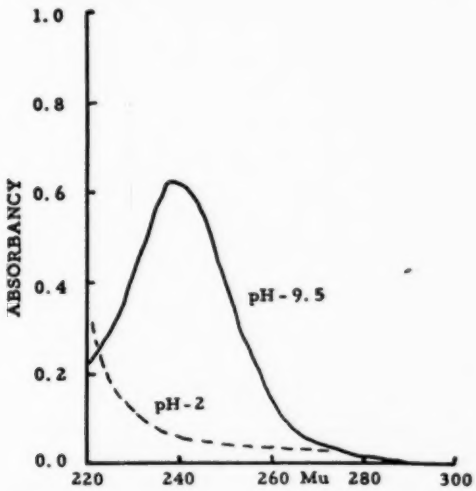

Fig. 1—Spectrogram of extract of fresh liver.

Putrefaction of Liver Containing Barbiturate

An intact section of liver weighing 150 grams was placed in a museum jar equipped with a loose-fitting cover. Ten grams of liver were removed for analysis at intervals, chosen arbitrarily, at 0, 2, 9, 12, 17, 21 and 90 days after autopsy.

Two days' exposure to air produced an increase in the concentration after spectrophotometry and paper chromatography. However, the results were still compatible with those obtained when the fresh sample of liver was analyzed in the same way.

Evidence that the process of decomposition was well under way, aside from the obvious physical signs, was first observed

when the 5-day sample of liver was analyzed. There was partial neutralization of the alkaline solution which necessitated a second extraction of the combined chloroform extracts. Spectrophotometry of the final extract resulted in the higher barbiturate level of 12.4 mg. per 100 grams of liver. Calculation of the level based on the amount of pentobarbital eluted from the chromatogram gave a concentration of 9.4 mg. per 100 grams of liver. Elution of the rest of the sheet section by section showed no remarkable accumulation of other extractable substances which would interfere with the evaluation.

Analysis of the 9-day sample of liver showed a slight difference in the configuration of the alkaline absorption spectrum. Instead of rising directly from 220 mu to the usual maximum at 239 mu, there was a slight drop to 230 mu where it then rose up to the expected maximum. The level obtained here was 13.7 mg. pentobarbital per 100 grams of liver. The calculation based on elution of the Rf 0.73 zone of the chromatogram gave 11.3 mg. pentobarbital per 100 grams of liver. This gradual increase in concentration of pentobarbital could be attributed to a diminution of protein in the liver resulting in less retention of the barbiturate. It was obvious that a gradual accumulation of substances produced by the splitting of protein and carbohydrate into simple compounds could now be realized. A higher dilution of the alkaline extract was necessary. Elution of the whole chromatogram indicated a gradual increase in absorbing substances which as yet did not appear to encroach upon the pentobarbital concentrated at Rf 0.73.

The analysis of the sample of liver taken after 12 days of putrefaction showed an increase in the formation of absorbing material being extracted along with the barbiturate. Although examination of the final basic and acidic spectra would leave no doubts as to the presence of barbiturate, certain changes in the characteristic alkaline spectral pattern should be noted. From 220 mu there was a sharper slope as the absorptivity decreased and the slight rise to 239 mu did not appear until 235 mu. The level was 14.3 mg.%. There was an increase in material absorbing at 275 mu in both the basic and acidic solution as well as an increase in material

absorbing beyond 300 mu. An effort to eliminate some of these substances by extracting the acid extract, after spectrophotometry, at pH-7 was not too successful. The level after this treatment was 13.5 mg.%.

The most drastic changes, in all respects, were first observed in the sample studied after putrefaction had continued for 17 days. The liver was extremely liquefied and most odoriferous. The observed value was 30.8 mg. pentobarbital per 100 grams liver and the level of 24.1 mg.% obtained after an extraction at pH-7 reflected the progress of the decomposition. Calculation based on the elution of the chromatogram was 14.8 mg.%. Isolation by elution of the pentobarbital at Rf 0.73 was made difficult by the presence of phenolic acid(s) bordering the zone customarily occupied by the pentobarbital. Overlapping of zones hampered clean separation. It is probable that the phenolic compound reported by Curry (5) as being isolated on paper chromatograms of liver extracts is present here. The concentration if calculated as pentobarbital did not exceed 1.0 mg. per 100 grams liver in this instance, as well as in the 21- and 90-day samples of liver analyzed below. The presence of intact pentobarbital at its customary location, however, was unmistakable.

Routine extraction of the acid filtrate from liver which had putrefied for 21 days was carried out. The interesting observation here was that the basic and acidic ultraviolet spectra no longer were truly characteristic of the barbiturates in that there was no rise to the maximum at 239 mu at pH-9.5 but rather a gradual slope downwards. This was due to an increase of masking absorbing substances, and higher dilutions were necessary. The level based on such a direct extraction was 34.3 mg. pentobarbital per 100 grams of liver. Extraction at pH-7 of the extract after spectrophotometry, while not changing the level too drastically (29.4 mg.%), did nevertheless produce a cleaner extract as evidenced by an improvement in the spectral pattern. Here, at pH-7, the final extract was the equivalent of 8 ml. diluted twenty times. It might be mentioned that for fresh liver there was a total of 8 ml. of final alkaline solution diluted only five times. Only after chromatography were the truly typical ultraviolet patterns unequivocal. The steady increase of phenolic acids is ever

apparent. A concentration of 14.8 mg.% based on the elution of the bordering pentobarbital zone was found. The value of the additional step of paper chromatography is fully appreciated in the final appraisal when one considers the drop from 34.3 mg.% obtained by direct extraction to the 14.8 mg.% after chromatography.

The liver which had been allowed to remain in air for a total of 90 days was analyzed. At the end of that period of time it was extremely dry and had partly solidified. The results, in every way, were remarkably similar to those obtained for the sample which had decomposed for a total of 3 weeks. The level found after extraction of the original acid filtrate was 44.3 mg.%, and the extract was diluted six times more than that of fresh liver (Fig. 2). After extraction at

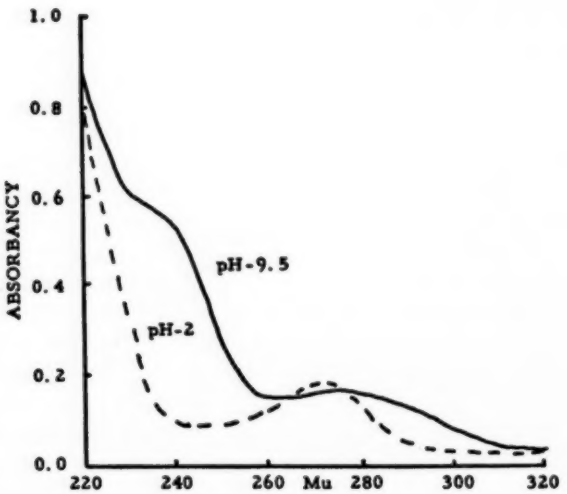

Fig. 2—Spectrogram of extract of putrid liver (diluted six times more than Fig. 1).

pH-7 the level was reduced to 31.6 mg.%. Pentobarbital was eluted from the chromatogram to give a concentration of 14.1 mg. per 100 grams of liver. The barbiturate was concentrated at its expected position of Rf 0.73, and reacted in the same way as the pentobarbital extracted from the liver in its

fresh state. Identification was based on the characteristic ultraviolet spectra at pH-2, 9.5 and 14 as well as from the chromatographic study with final application of the usual reagents.

It should be noted that nowhere during the above study were any of the known metabolic degradation products of pentobarbital discerned (6), (7), (8), their possible presence being considered. In all instances where extraction at pH-7 was accomplished, a re-extraction of the pH-7 residue was carried out at pH-2, followed by a paper chromatographic study which would reveal the carboxylic acid metabolite of the pentobarbital if present.

The results of this study are presented in Table I.

TABLE I

Observed Concentration of Pentobarbital in Putrefying Liver

Days of Putrefaction	*mg./100 grams Extraction*		
	pH-2	*pH-7*	*After Chromatography*
0	9.2	—	6.9
2	10.2	—	8.2
5	12.4	—	9.4
9	13.7	—	11.3
12	14.3	13.5	—
17	30.8	24.1	14.8
21	34.3	29.4	14.8
90	44.3	31.6	14.1

Putrefaction of Normal Liver

An intact section of liver from an adult female who had succumbed as a result of an automobile accident was allowed to decompose in air under the same conditions as observed for the preceding study. The samples of liver were removed for analysis after the same time intervals, and the basic procedure strictly followed. The extract of liver analyzed soon after autopsy was negative for barbiturate and produced ultraviolet spectra and a paper chromatographic pattern

similar to those obtained for other fresh livers known to be negative for barbiturate.

In no sample taken thereafter was there any indication of the presence of any compound which might be mistaken for a barbiturate. The results indicated attack by bacteria different from those effecting decomposition in the previous run. For the control liver, there was no apparent accumulation of stable acidic material, and in no instance was the original alkaline solution neutralized. Dilution of final extracts for spectrophotometry was at a minimum, the highest one necessary being 8 ml. diluted 3 times. There were indications of the formation of phenolic substances starting 2 days after putrefaction, but these were apparently volatile and labile in nature and could not be found after elution of the chromatograms. The liver itself seemed less odoriferous, and there was gradual dehydration rather than liquefaction which in the first study reached its peak after 2 weeks in air.

Formalin-Fixed Liver Containing Barbiturate

Another section of the barbiturate-containing liver, weighing 130 grams, was placed in 2100 ml. of formalin (4% by weight) soon after autopsy. After 44 days, a 10-gram sample of liver was removed and analyzed according to the adopted procedure. A concentration of 1.3 mg. pentobarbital per 100 grams of liver was found after initial spectrophotometry. Calculation based on the amount of pentobarbital recovered from the Rf 0.73 zone of the chromatogram gave a level of 1.0 mg.%.

An appropriate aliquot (160 ml.) of the formalin in which the liver was fixed, proportionately representative of the 10 grams of the liver, was extracted directly with two 50 ml. portions of chloroform, and the procedure continued as for liver. The amount of barbiturate found after spectrophotometry represented a level of 7.2 mg.% which with the accompanying figure of 1.3 mg.% gave a total concentration of 8.5 mg. pentobarbital originally contained per 100 grams liver when it was placed in the formalin. Chromatography of this extract gave a concentration of 5.6 mg.% which with its accompanying level of 1.0 mg.% stated above results in a concentration of 6.6 mg. pentobarbital per 100 grams liver.

In no instances were interfering substances encountered either in extracts taken for spectrophotometry or in eluates from the chromatograms. The levels found corresponded with the results obtained when fresh liver was analyzed.

After a total of 162 days in formalin, the same procedure was again followed, with substantially the same results.

The results of this study are presented in Table II.

Barbiturate-Containing Liver Fixed in Embalming Fluid

A third section of the barbiturate-containing liver weighing 120 grams was placed in 500 ml. of embalming fluid. The choice of the embalming fluid was strictly a random one. A sample of the arterial fluid customarily used by one of the largest local funeral homes was provided upon request and without any preliminary inquiries.

A 10-gram sample of the liver was removed for analysis and the representative aliquot of the liquid in which it was bathed for a total of 42 days. The procedure used here was the same as that for liver fixed in formalin above except that all extractions with chloroform had to be made from a pH-7 buffered solution in order to eliminate the pink coloring material and other compounds present in the embalming fluid which were found to interfere with the ultraviolet spectrophotometry.

A concentration of 2.2 mg. pentobarbital per 100 grams liver was found which, together with a finding of 5.1 mg. pentobarbital per 100 grams liver based on the amount found in the aliquot of fluid representing the equivalent amount of liver, gave a total of 7.3 mg.%. After chromatography it was calculated that there was a total concentration of 4.1 mg. pentobarbital per 100 grams of liver.

After 164 days, the total concentration based on spectrophotometry was 8.1 mg. of pentobarbital per 100 grams of liver with the bulk of the barbiturate in the proportionate sample of fluid being equivalent to 6.2 mg.%.

The results are presented in Table II.

Fixing of Normal Liver in Embalming Fluid and Formalin

Sections of normal liver from the same accident case as used above were fixed in embalming fluid and formalin using

the same relative proportions as for liver which contained the pentobarbital. As above, both the liver and the medium in which it was immersed were analyzed after the same periods of time.

TABLE II

Concentration of Pentobarbital in Fixed Liver

		mg./100 grams					
		Before Chromatography			*After Chromatography*		
Medium	*Days Fixed*	*Liver*	*Fluid*	*Total*	*Liver*	*Fluid*	*Total*
Formalin	44	1.3	7.2	8.5	1.0	5.6	6.6
Formalin	162	1.3	8.1	9.4	1.0	6.1	7.1
Embalming fluid	42	2.2	5.1	7.3	1.0	3.1	4.1
Embalming fluid	164	1.9	6.2	8.1	2.2	5.3	7.5

The routine paper chromatograms prepared from extracts of liver and embalming fluid in which they were bathed did not reveal the presence of any significant absorbing materials after the 5½ month period.

After 5½ months in formalin, phenolic acids could be detected on the chromatograms of extracts of both liver and formalin by ultraviolet spectrophotometry of eluates and by application of diazotized sulfanilic acid and Folin-Ciocalteu reagents (9, 10) indicating the start of some decomposition. The extent of decomposition was minor, and the negative results obtained where embalming fluid was the fixative are apparently due to the extractions being carried out at pH-7, rather than its greater efficiency as a fixative. Chromatograms of extracts of fresh normal liver treated with diazotized sulfanilic acid were found to be negative.

Discussion

That pentobarbital is able to withstand the effects of cadaveric decomposition is attributed to the formation of reducing substances in an acid medium as the processes of putrefaction get under way. These reducing substances would tend to retard oxidation of the barbiturate. It was recognized from the start that this study would represent only one of the many possible mechanisms of cadaveric decomposition and that the many variables possible such as heat, humidity, bacteria, and locale, individually and jointly, would influence

the course of decomposition. The fact that the liver in this case was removed from the cadaver and then allowed to putrefy in a glass jar is a deviation not without implications in regard to medicolegal investigation. In spite of this, the over-all effects can be reduced to a few relevant conclusions. The pentobarbital was not altered under the experimental conditions which involved its subjection to rather drastic treatment in a complex organic medium for as long as 3 months.

It is brought out that once decomposition is well under way, no reliance should be placed on the amount of barbiturate determined solely by ultraviolet spectrophotometric analysis, *but some additional step such as paper chromatography must be used to eliminate interfering substances.* It is noteworthy that after 17 days of putrefaction when the most drastic influences are in full force, the results from the chromatographic study agree with those levels obtained after 3 and 12 weeks of putrefaction. The concentration in the range of 14.8 mg. of pentobarbital per 100 grams of liver, though differing from the earlier findings, still allow for a reasonable appraisal in the usual medicolegal cases provided that not only the particular barbiturate be identified but also that allowance be made for effects of putrefaction. The reasons for the gradual increase in concentration after chromatography can be attributed to interference of material from bordering zones and on the fact that less barbiturate is retained by protein as well as concentration of barbiturate due to loss of water with subsequent loss of weight of decomposing material.

The findings from the study of the fixed liver were interesting, and the agreement between levels obtained after one month and almost six months was gratifying.

It should be emphasized that the practice of lumping together assorted organs in fixing medium be avoided, and that the original surrounding fluid always be retained in consideration of the ever-present possibility of re-opening of cases after storing of tissue.

The described technique has found most useful application in this laboratory. The resolution of one interesting case depended upon the results of analysis of liver which had been removed from an embalmed body prior to burial. The pres-

ence of three barbiturates in the liver was established. Each was identified, and the ratios obtained were referred to the original level determined for total barbiturate. Concentrations of 2.0 mg. of phenobarbital, 8.5 mg. of seconal, and 8.9 mg. of pentobarbital per 100 grams of liver were found.

Summary

Liver from an adult human who had succumbed to barbiturate poisoning was allowed to putrefy in air for 3 months.

The liver was analyzed for pentobarbital using ultraviolet spectrophotometry and paper chromatography after 0, 2, 5, 9, 12, 17, 21 and 90 days of decomposition.

Unchanged pentobarbital was recovered from the liver after 3 months of putrefaction.

Fresh portions of liver from the same case were fixed in formalin and embalming fluid. Unchanged pentobarbital was recovered from the liver and surrounding medium after 5½ months.

One case is discussed in which liver removed from an embalmed body prior to burial was analyzed for barbiturate. Three barbiturates were found to be present; each was identified and the individual levels reported.

Acknowledgment: The author is grateful to Michael A. Luongo, M.D., for suggesting this investigation and for his continued help and interest during the course of the study.

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AMERICAN ACADEMY OF FORENSIC SCIENCES

Proposed Program for 1958 Annual Meeting

February 27, 28 and March 1, 1958

Carter Hotel, Cleveland, Ohio

Thursday morning ....“What's New in Forensic Pathology”

Thursday afternoon ...Sectional Meetings

Thursday, 5:00 PM....General business session

Friday .....Symposium—“The Investigation of Sudden, Unexpected or Obscure Deaths”

[Each section is expected to participate in this symposium.]

Friday night.....Banquet

Saturday morning.....Sectional meetings, and joint meetings of one or more sections, to be arranged by Section Chairman. Possible alternative program—Symposium on the Control of Experimental Observations and Analytical Procedures in Forensic Science.

General Program Chairman: Russell S. Fisher, M.D.
Chief Medical Examiner
700 Fleet Street
Baltimore 2, Maryland

Primary Intracranial Neoplasms in a Medicolegal Autopsy Service*

Robert W. Huntington, Jr., M.D., Bakersfield, Calif.

Experience with Primary Intracranial Neoplasms in a Medicolegal Autopsy Service

There is an increasing awareness that primary intracranial neoplasms, once considered very rare except in large neurosurgical clinics, are actually rather common. While the traditional county doctor who reported a busy practice of 40 years without ever seeing a brain tumor was doubtless candid, one would suspect that the lack was one of recognition rather than of occurrence. It is acknowledged that the diagnosis of intracranial tumor prior to autopsy, may elude the most skillfull and suspicious clinician. A recent text (1) has a trenchant paragraph on the importance of such tumors in forensic pathology. However, if the experience to be presented is at all representative, this is a topic which may merit further emphasis and illustration.

The Kern County Pathology Department does autopsies both for the county coroner and the county hospital. The compulsion to learn something about primary intracranial tumors has come almost as much from the coroner's as from the hospital service. It is a pleasure to acknowledge a debt to Dr. James W. Kernohan (2) for advice and instruction which have been both learned and gracious. The interest which he expressed in some of the "coroner's tumors" suggested that

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, February 28–March 1, 1957, Chicago, Illinois.

their histology was perhaps almost as bizarre as their history. Possibly brain tumors which reach a coroner's service might tend to be different from the commoner types on a neurosurgical service. If there is substance to this suspicion, perhaps it might be appropriate for forensic pathologists to pool their experience both in the history and in the histology of intracranial neoplasms. Perhaps this is a field of oncology with a specific challenge to forensic pathologists.

In the period April 15, 1950 to January 28, 1954, 1,000 coroner's autopsies were performed (including 275 "hospital and coroner's" (3), together with 911 "straight county hospital" autopsies. Among the 911 hospital autopsies there were 8 cases of primary intracranial tumor and in the coroner's series there were 6. Of the 41 neoplastic deaths in the coroner's series, bronchogenic carcinoma account for 7, (4) while intracranial tumors and lymphomas were tied for second place with six each. One of the six intracranial tumor cases was that of a white woman of 41 whose husband was alleged to have hit her. She proved to have both an early squamous cell carcinoma of the cervix and a grade III cerebral astrocytoma (5). Another was that of a 60-year-old white woman who became comatose in a dubious family situation. She, too, proved to have a grade III cerebral astrocytoma. The third was that of a 51-year-old woman who died at another hospital immediately after a lumbar puncture and was found to have a cerebellar hemangioblastoma. Practically no medical history was available. The diagnosis of intracranial neoplasm had been at least entertained in the first case, but had been entirely unsuspected in the other two.

The remaining three cases from this series, together with two cases from subsequent autopsy experience, and a final one which was not referred by the coroner, will be given in a little more detail. In the first, the problem prior to autopsy was that of traumatic hematoma versus neoplasm. In the second the history seemed to raise the question of metal fume poisoning. The third illustrates the abrupt conclusion of a child's illness which had been considered probably psychogenic. The fourth (from experience subsequent to the 1000 tabulated cases) was a bizarre instance of association of pituitary tumor with purulent meningitis. The fifth exempli-

fies an unusual exitus for an alcoholic. The last, the only one presented which did not reach us by the coroner, is that of an individual serving a jail sentence for what in retrospect was obviously personality change due to an expanding lesion.

Case No. 1 (C147–51). This 33-year-old white man was working near a tamping machine when the tamping rod broke. He received

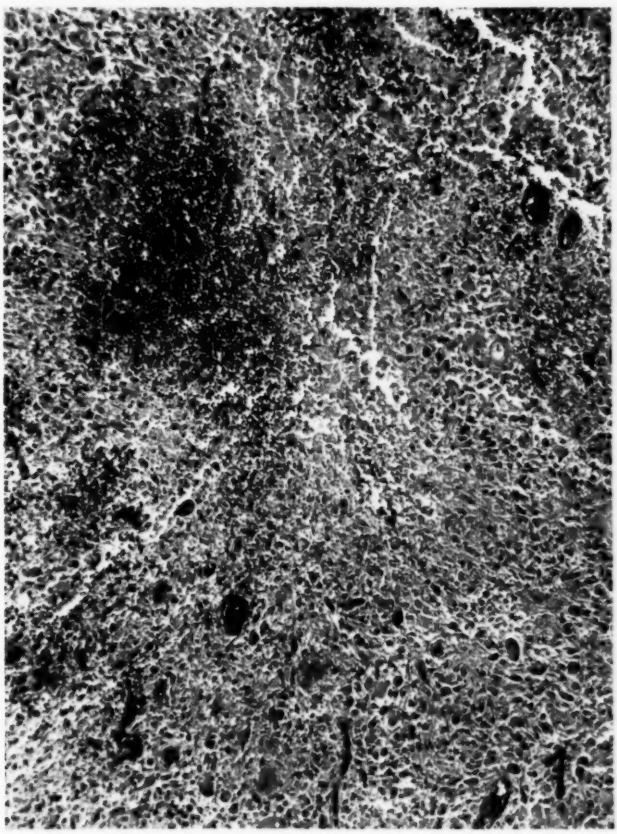

Fig. 1—Case 1. Tumor showing areas of hemorrhage.*

* The microphotographs were taken by Mr. Lloyd Matlovsky, through the cooperation of the Tumor Tissue Registry of the California Cancer Commission.

a rather severe blow to the head from a flying piece of wood, and was stunned for a few moments. He resumed work, but the next morning he began to be progressively sleepy and nauseated. He was admitted to a private hospital a week later. Burr holes were

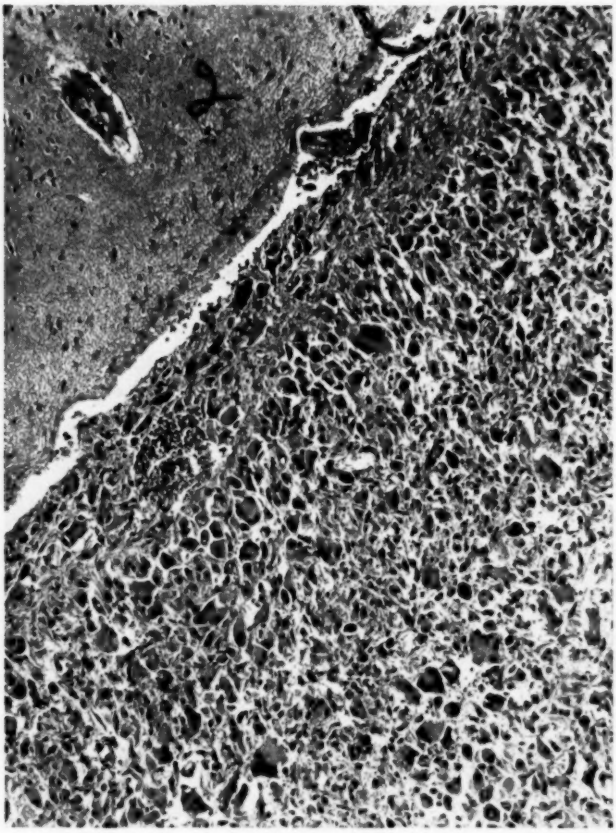

Fig. 2—Case 1. Tumor tissue, showing cellular pattern.*

drilled, and blood could be evacuated from the ventricles, but not from the neighborhood of the dura. The patient died about 12 hours after this procedure. At autopsy there was a gash on the right index finger which appeared to be several days old. There was hemorrhage

* The microphotographs were taken by Mr. Lloyd Matlovsky, through the cooperation of the Tumor Tissue Registry of the California Cancer Commission.

in the scalp about the burr holes. The calvarium was not fractured. The brain weighed 1670 grams and showed a definite cerebellar cone. When cut after formalin fixation it showed leftward displacement of the right lateral ventricle by a mass consisting of a central cyst

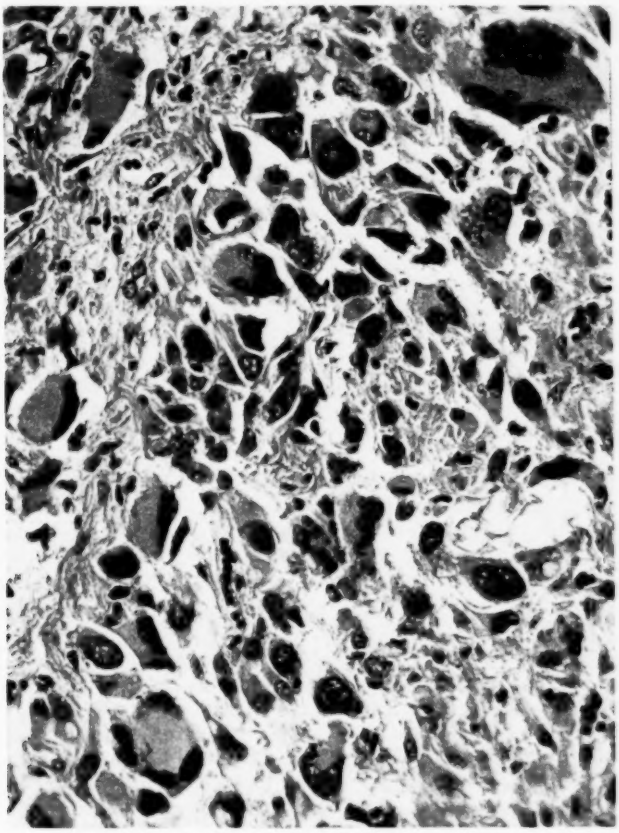

Fig. 3—Case 1. Detail of giant cells.*

with surrounding soft tissue. Microscopic sections showed an extremely anaplastic and pleomorphic tumor summarized by Dr. Kernohan (3) as "astrocytoma grade four squared," or extremely anaplastic glioblastoma multifore (5). The tumor was hemorrhagic and

* The microphotographs were taken by Mr. Lloyd Matlovsky, through the cooperation of the Tumor Tissue Registry of the California Cancer Commission.

necrotic in some areas, and well-preserved in other. It was very vascular.

While no suggestion that the blow might have caused the tumor could be countenanced, the possibility that the blow might have hastened death by causing hemorrhage into the tumor could not be flatly denied. There was no reason to think that tumor-induced clumsiness had anything to do with precipitating the accident. It is reported that a settlement between the widow and the industrial compensation carrier was approved by the industrial accident commission.

Case No. 2 (C66–50). This 32-year-old white man had been working for an aircraft manufacturing company for 10 years. For the past 5 years he had been a spot welder. His predecessor had committed suicide in the course of what was said to be "an incurable illness," and at the present subject's death, rumors gathered fast. On August 11, 1950, he had been to a dentist "to have some abscessed teeth extracted." His only previous complaint had been of vesicles on the fingers which would appear and disappear. On August 21 he had first noted a tendency to stagger. He ceased working on the next day. He consulted a general physician, an otologist, and a highly competent neurosurgeon, who were unable to make an organic diagnosis. The neurosurgeon reported normal eyegrounds. The subject was brought to Bakersfield by his parents, who felt that his wife, in a coastal city, needed relief from the strain of nursing him. He became disoriented. On September 13, he was seen by an osteopathic physician who gave him antibiotics on the assumption of a sinus infection. On September 15 he lay down for a nap and was later found dead.

At autopsy the thoracic and abdominal viscera were not remarkable. The brain weighed 1440 grams, with obvious edema, flattening of the convolutions, and a large cerebellar pressure cone. While the brain was being fixed the blood was studied for metals by the Industrial Hygiene Laboratory of the State Health Department and the working conditions at the factory were investigated by the Industrial Hygiene Division of the Los Angeles County Health Department. The County Health Department reported nothing untoward; the State Laboratory found no manganese, cadmium, arsenic, or antimony and the lead value was in the normal range (0.15 mgm/100 gm blood). The brain was now cut, and a soft mass was found in the left cerebellar hemisphere which had not been suspected on external examination. It occupied about one half of the left cerebellar hemisphere and encroached on the pons. Sections showed an extremely cellular infiltrating tumor. The cells were polygonal, with vesicular nuclei. Cells occurred both in small clumps and singly. Multinucleated cells were present, and mitoses were common. Large and small vessels were conspicuous.

Dr. Kernohan indicated that while this tumor was novel in his experience, he felt that it must be considered a high-grade cerebellar astrocytoma (2). Since the neurosurgeon was extremely surprised by this symptom complex, one might suspect that such tumors in adults are not often seen by neurosurgeons. If they are at all common, possibly the forensic pathologist may be the physician most likely to see them. We should be particularly grateful for any accounts of similar experience.

Case No. 3 (C61–51). This white female child, born in 1941, was first seen by a pediatrician in January 1950 on account of vomiting and nervousness. During the year she did well and gained weight, despite several episodes of vomiting which usually occurred when her salesman father, to whom she was devoted, was on the road. On April 30, 1951, she became obviously ill, with acetonuria. Examination showed recent weight loss. The following neurologic findings were recorded. Romberg negative on wide and narrow base. Finger to nose done rapidly and well. Pupils round, equal, reactive. Fundi and discs normal. Deep and superficial reflexes equal and active. Pain and position response showed on abnormalities. She did well for 24 hours following this office visit and then began vomiting again. On admission to a private hospital on May 3 she complained of diplopia and constant headache. Vomiting was occasionally projectile. Skull x-rays were not remarkable. Spinal fluid showed slight increase in protein. Immediately after lumbar puncture the child said she felt better. However the next day she developed hiccups and slow respiration. It was decided to repeat the lumbar puncture prior to neurosurgical consultation. Respiration ceased during this procedure.

At autopsy, thoracic and abdominal viscera were not remarkable. After removal of the brain from the calvarium, a soft, light-colored hemorrhagic globular tumor mass was seen attached to the lower aspect of the cerebellum in the midline, and immediately covering the medulla. The surrounding cerebellum was soft and hemorrhagic. There was considerable clotted blood about the cervical spinal cord. The ventricular system was much dilated. The dural sinuses were congested.

The tumor was very cellular, and the majority of the cells had vesicular nuclei and indistinct cell boundaries. After consideration of such possibilities as ependymoblastoma and primary intracranial sarcoma, it was decided that this tumor was best classified in the broad and rather variegated group of medulloblastoma.

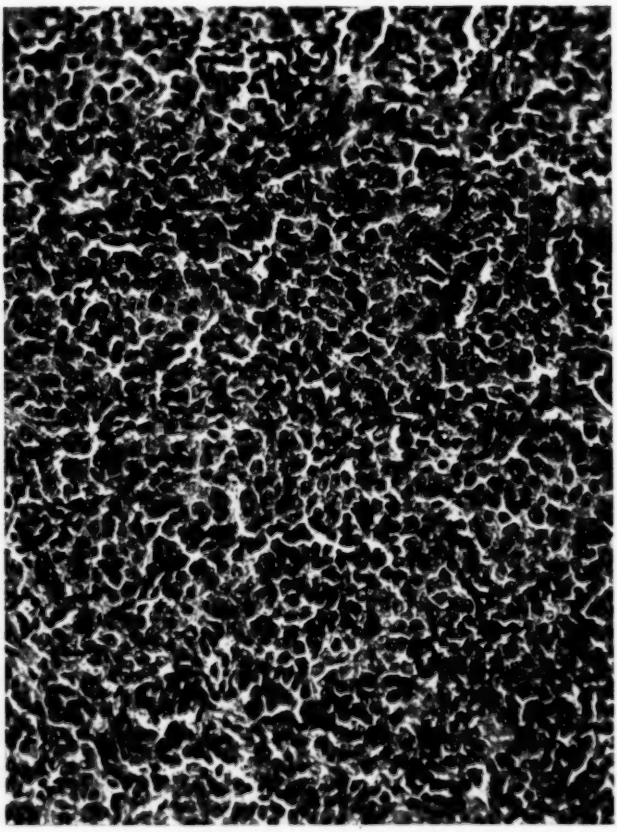

Fig. 4—Cellular pattern of tumor in case 3.*

Case No. 4 (C29–54). This 63-year-old white woman was reputed to be a character who lived by herself and had a low opinion of doctors. She was found in coma on the morning of March 8, 1954, and was taken to the West Side District Hospital where she was found to have high fever and cloudy spinal fluid. She died in a few hours despite heroic antibiotic therapy. Since from the public health standpoint it was desirable to determine the etiology of the meningitis, the case was referred to the coroner. At autopsy there was extensive

* The microphotographs were taken by Mr. Lloyd Matlovsky, through the cooperation of the Tumor Tissue Registry of the California Cancer Commission.

necrosis and inflammation in the neighborhood of the sella turcica, which communicated with the sphenoid sinus. Cultures from the sella showed hemolytic streptococcus. Provisional anatomical diagnoses were osteomyelitis of the base of the skull due to sphenoid sinusitis, and necrosis of the pituitary due to infection. Microscopic examination of the brain showed leptomeningitis to be much more extensive than was suspected in the gross. Fortunately, upon the suggestion of a sagacious resident, all the sellar contents were put into fixative, even though to the pathologist (RWH) they looked like nothing more than necrotic debris. Microscopic examination enabled one to recognize, in the midst of the inflammation, an anaplastic pituitary tumor with extension to dura and periosteum. The mucosa of the sphenoid sinus did not show tumor.

In summary, a 63-year-old woman developed a fistula between the sella and the sphenoid sinus which led to purulent meningitis. A surprise on microscopic examination was an anaplastic pituitary tumor. It is a little hard to think that this was unrelated to the fistula.

Case No. 5. A 37-year-old white female went to a physician's office in the afternoon of December 28, 1955. One of her two male companions (both apparently unrelated) paid the bill. She complained of "the shakes" and appeared intoxicated. History obtained subsequently included much drinking and some threats of suicide. She was given vitamins, phenacetin with codein, and 30 tablets of ½ grain phenobarbital. One of the male companions prudently took all but one of these last away from her before leaving her at her lodging. During the night she began to vomit. She was dead when the doctor arrived at 11:20 p.m.

Autopsy revealed a marital outlet. There was no evidence of trauma there or elsewhere. Blood and gastric contents were negative for barbiturates. Blood alcohol was negative. The lungs were somewhat congested. Other thoracic and abdominal viscera were not remarkable. The brain weighed 1560 grams and there was a large cystic tumor in the right frontal area. Microscopically this was a high-grade astrocytoma, in some areas almost as pleomorphic as that of case No. 1.

This was an unusual mode of death for an alcoholic. It does not encourage belief in the protective effect of alcohol against brain tumors.

Case No. 6. This case, as already mentioned, was not referred by the coroner. However, it has sufficient forensic interest to justify its presentation.

This 44-year-old white man, who had previously been alert and industrious, became shiftless and lethargic. On account of failure to support his family he was sentenced to a year in the county jail. He complained of frontal and parietal headache. However no attention was paid to his physical status until some months after the beginning of his sentence, when other prisoners began to complain of the nuisance of having to look after this blind man. Clinical and laboratory examination then revealed little other than blindness, apathy, and marked elevation of spinal fluid protein (361 mgm%). While awaiting air study he became increasingly lethargic and eventually stuporous. He had a generalized convulsion. Breathing became shallow, and pupils were noted to be dilating and contracting spontaneously. Reflexes were hypoactive, and there was a positive Babinski reflex bilaterally. He gradually came out of his stupor, and on January 22, 1951 was reported alert and rational. Air study was done on January 25 and was immediately followed by craniotomy. A large tumor was found over the frontal lobe. He expired during surgery. At autopsy there was residual tumor invading the skull. Most of the tumor had been removed surgically. It was a meningioma of the meningothelial type.

Summary and Conclusions

Primary intracranial tumors have presented themselves under circumstances which suggested trauma, industrial poisoning, and post-alcoholic or barbiturate withdrawal state. They have been implicated in abruptly fatal purulent meningitis, in abrupt death in an illness long considered functional, and in personality change leading to incarceration. The compulsion to become brain tumor minded has reached the writer and his residents as much from their coroner's service as from their hospital service. Unless this experience is a statistical freak, it would seem that primary intracranial tumors may constitute an area of oncology with particular challenge for forensic pathologists.

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The Seventh Annual Seminar for Police Officers—"Investigation of Homicide"—will be presented by The Kettering Laboratory of The University of Cincinnati, November 11 through November 16, 1957.

For further information, contact Dr. Frank P. Cleveland at The Kettering Laboratory, Cincinnati 19, Ohio.

FELLOWSHIP IN FORENSIC MEDICINE

Department of Pathology, Western Reserve University
Cleveland, Ohio

Training in Forensic Medicine is offered to qualified individuals with a minimum of three years experience in general pathology. The appointment is for one year, and the period of training is accredited by the American Board of Pathology. The annual stipend is $5,000.

The practical work is carried on in the new Cuyahoga County Coroner's Laboratories located on the campus of Western Reserve University and includes approximately 1200 medicolegal autopsies per year.

Personnel and facilities for training in gross and microscopic pathology, forensic chemistry (toxicology), gross and microphotography, trace evidence and forensic immunology are excellent. Fellows will have an opportunity to participate in "on the scene" investigation of violent, suspicious and unexplained deaths. Instruction is provided in the administrative aspects of the modern medicolegal office and legal procedures affecting forensic medicine. An active research program is in progress in several phases of forensic medicine.

Experience in courtroom work is an essential part of the program and special attention will be devoted to instruction in the presentation of medical evidence in civil and criminal proceedings, both in trial courts and before the Grand Jury and Industrial Commission.

The Cuyahoga County Coroner's Office is an integral part of the Law-Medicine Center of Western Reserve University where courses are offered throughout the year to attorneys, law students, physicians, medical students, law enforcement officials, etc. Fellows will be encouraged to participate actively in the teaching program.

Blood Grouping Tests in Uncontested Paternity Proceedings*

Leon N. Sussman, M.D., F.A.C.P., and Sidney B. Schatkin, LL.B., New York, N. Y.

Numerous reports concerning the usefulness of blood grouping in disputed paternity proceedings have appeared in the literature and have been presented before this academy in the past few years (1–10). The infallibility of an exclusion based on blood tests has been firmly established and the courts in many states have accepted such exclusions as decisive of the issue. It is with pride that we can say the pioneer work in this field has been done by our fellow academicians, Drs. Wiener, Unger, Schatkin and others (11).

However, it is only a minority of defendants in paternity cases who request blood tests; these are the men who deny the accusations. Studies in the past, limited to these cases of disputed paternity proceedings, have shown that 30–40% (5, 8, 9, 10) of the men who deny paternity are truly falsely accused. This present study was undertaken to determine the results of blood grouping tests in those cases where the defendants admit paternity, that is, in undisputed paternity proceedings.

Method of Study:

All of the cases examined had been settled by the admission of paternity by the defendant. The court had already imposed awards for support and expenses, and the cases were closed.

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 1, 1957, Chicago, Ill.

Subsequent to this, the litigants were approached and asked to voluntarily submit to blood grouping tests. This latter task was understandably frustrating. Over a 3-year period, during which time 500 litigants were interviewed, it was only possible to complete 67 family studies. It is these 67 cases that are the basis of this report.

The tests were performed in the usual manner of duplicate testing by separate technicians using different lots of serum. ABO groupings were performed by direct cell typings with known anti-**A** and anti-**B** serum, and anti **A** + **B** (**O**) serum and reverse typings, using known A cells and B cells with the serum being tested. M–N groupings were performed by four anti-**M** and four anti-**N** rabbit serums by well-slide and test tube techniques. Rh-Hr groupings were determined by use of saline and "stick" tests with known **Rh$_0$**, **rh′**, **rh″**, **hr′** and **hr″** antisera in duplicate. Negative reactions were checked by use of antiglobulin techniques where pure or unblocked serum * was used for the testing. Positive and negative controls were incorporated in each run. In addition to the accepted blood systems advised by the AMA report on the "Medical Legal Application of Blood Grouping Tests" (12), additional tests were done with anti-**Kell** serum and anti-**P** serum.

Results:

The results obtained indicate that of 67 men involved in these cases of uncontested paternity actions, there were 6 instances in which the blood tests excluded the putative father. The exclusions obtained are demonstrated in Table 1. It has been shown in previous publications that blood grouping tests, using the ABO, MN, and Rh–Hr systems can only exclude 50.8% (8) of falsely accused men. It follows, therefore, that in this small series, in fact 12 or 18% of the accused men who admitted paternity are not the fathers of the children they accept as their own.

* "Pure" or unblocked serum refers to a serum containing only a single antibody. Thus a pure **rh″** antiserum is obtained from a sensitized donor whose phenotype is Rh_1rh, thus lacking the **rh″** factor. A blocked **Rh$_0$″** antiserum is not suitable for the antiglobulin test for this purpose as the test would be falsely positive due to coating of the test cells by the univalent **Rh$_0$** antibody in the blocked serum.

It is also of interest then even in this small series exclusions were obtained not only by the ABO and MN tests, but also by the Rh-Hr types (Table 2). This re-emphasizes the importance of using all the available blood groups systems in medicolegal blood testing. Failure to determine the Rh-Hr types in these cases could have resulted in overlooking 2 of the 6 exclusions obtained. As more of the blood group systems such as P, Kell, Duffy, and others are statistically established and more liberal supplies of standardized testing serums become available, these blood groups will increase the percentage of probable exclusions obtainable. To gain this increased effectiveness, the medicolegal aspects of blood grouping (12, 13, 14) should be restricted to recognized experts whose laboratories are becoming more and more easily available because of rapid air transportation.

An additional area of interest was explored in examining the reasons why an accused man admits paternity, an admission which, at best, is only a presumption. The answers given fall into one of the following:

1. A sincere belief that he is the father.
2. A sense of pride in that he could be the father.
3. A total moral and financial irresponsibility which leads to a careless attitude toward the situation.
4. Inability to afford legal defense or cost of blood tests.
5. A state of ignorance which confuses intercourse with paternity. This latter state presenting itself so often as to convince the interviewer that sex education is sadly neglected.

Summary:

The findings by means of blood grouping tests that 18% of men who admit paternity are not the fathers of the children they accept suggest strongly the need for re-evaluating such admissions. Serious doubt can now be placed on the reliability of such admissions of paternity, which are so routinely accepted by the courts. In the interests of justice, it would seem that a blood grouping test be mandatory in every case involving a charge of paternity.

Table 1—Blood Test Exclusions Obtained in 67 Uncontested Paternity Proceedings

No.	Putative Father	Mother	Children	Excluded by System
1(Case 2)	O N Rh_2rh	A_2 MN Rh_2rh	A_2 M Rh_1rh	M–N, Rh–Hr
2(Case 8)	O MN Rh_0	O M Rh_0	(a) O M Rh_0	Not excl.
			(b) A_1 M Rh_0	A–B–O
3(Case 16)	O MN Rh_0	B MN Rh_1Rh_1	(a) O N Rh_1Rh_1	Rh–Hr
			(b) O N Rh_1rh	Not excl.
			(c) B MN Rh_1rh	Not excl.
4(Case 21)	B M Rh_0	B M Rh_0	A_1 M rh	A–B–O
5(Case 39)	O M Rh_2rh	O N Rh_0	(a) O N Rh_2rh	M–N
			(b) O N Rh_2rh	M–N
6(Case 56)	B N Rh_2Rh_0	O M Rh_0	A_1 MN Rh_1rh	A–B–O

[Table I reproduced with permission of the J. A. M. A., v. 164, #3, May 18, 1957, p. 249.]

Table 2—Blood Group Systems Resulting in Exclusion (7 children excluded in 6 cases)

Total	*ABO*	*MN*	*Rh-Hr*
7	3	3*	2

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Blood Bank Laboratory
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PLAN TO ATTEND

TENTH ANNUAL MEETING

AMERICAN ACADEMY OF FORENSIC SCIENCES

February 27, 28 and March 1, 1958

Hotel Carter Cleveland, Ohio

Dr. Samuel Gerber, Coroner Cuyahoga County
Chairman Local Committee on Arrangements
Cleveland 6, Ohio

Nalline: An Aid in Detecting and Controlling the Illicit Use of Narcotics*

Fred L. Braumoeller, A.B., and James G. Terry, M.D.,
San Francisco, Cal.

Nalline (N-allylnormorphine hydrochloride) is an antagonist used to reverse symptoms of excessive narcotism. It has a respiratory stimulating effect against the respiratory depression caused by morphine, methadone, Dilaudid, Dromoran, Levo-Dromoran, Pantapon, Demerol, Nisentil, codeine and heroin, but is not active against the depression produced by barbiturates, cyclopropane or nitrous oxide. Nalline is a narcotic with little or no analgesic effect and has three distinct clinical uses: "(1) The prevention and treatment of respiratory depression in the newborn, (2) the treatment of poisoning with narcotics, and (3) the diagnosis of physical dependence (active addiction) on narcotic drugs." (2) Dr. Harris Isbell (1, 2, 3) and his co-workers at the United States Public Health Service Hospital, Lexington, Kentucky, demonstrated that Nalline, when administered to a patient addicted to heroin, morphine, Dilaudid, or methadone, will produce withdrawal symptoms in a relatively short time. The drug apparently acts upon the central nervous system in such a way as to nullify certain effects of narcotics. As a result, Nalline can be used as final proof of suspected narcotic addiction.

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* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 2, 1957, Chicago, Illinois.

Research

During the period of research from March 1955 to March 1956, 103 persons were tested with Nalline.** Among them were known users of opiates, suspected users of opiates, and non-users of opiates or other narcotics. It was concluded that observation of withdrawal symptoms alone should not be depended upon for a diagnosis, because false withdrawal symptoms occur in some cases.

Sometimes when 5 mg. of Nalline is given, a person who has not been using opiates may have a reaction that resembles withdrawal symptoms of Plus 1 magnitude (5). Perspiration, nausea, apathy, and peripheral vaso-constriction have been noted in such circumstances. In these Nalline reactions, in contrast to Nalline inter-reacting with an opiate, the pupils constrict markedly. The pupillary response alone is an accurate, sufficient and sensitive index of narcotic addiction, or of occasional use, or of the absence of narcotics.

Because heroin is the opiate of primary importance in illicit narcotic traffic, controlled single doses of heroin were injected intravenously into post-addict volunteers. They were then tested with Nalline at intervals of 24, 48 and 72 hours. Two single doses of one-sixth grain of heroin hydrochloride administered at a 24-hour interval gave a negative response with Nalline 24 hours later. Two single doses of one-third grain of heroin hydrochloride administered at a 24-hour interval gave a positive response with Nalline 48 hours later. These results were verified by urinalysis (6).

Suspected addicts when ordered to take a Nalline test by their parole or probation officer, sometimes claimed to be using "Terpin Hydrate and Codeine" or Cheracol on prescription. Controlled tests in which up to 3 grains of codeine were administered per day for seven days were conducted. Nalline gave a negative response in all these cases, indicating that the above drugs, used in amounts as prescribed for cough would not affect the validity of the test. Later tests on persons using in excess of 12 ozs. of "Terpin Hydrate and Codeine" per day gave a positive response.

** Sharp and Dohme supplied the Nalline used in this study.

Technique

The technique of the test is simple. First, permission to give the test, in the form of an authorization and waiver, should be obtained from the suspect. The form used is shown in Figure 1. It should be signed by the suspect and witnessed.

Figure 1. Authorization and Release Form

AUTHORIZATION AND RELEASE

I, ——— ——— do, of my own free will, hereby expressly authorize and request the Officers, of the Oakland Police Department, the City of Oakland, a municipal corporation, James G. Terry, M.D., the State Bureau of Narcotic Enforcement, or the authorized agents of either of them, to administer an injection or injections of Nalline for the purpose of determining whether or not I am under the influence of Narcotics and for the purposes of treatment. I freely and voluntarily submit to these tests which I believe are for my own best interests.

For and in consideration of the foregoing, I authorize the use of the results of these tests in any way which these officials may feel is proper, and I do hereby expressly release, discharge, and exonerate all members and employees of the Oakland Police Department, the City of Oakland, a municipal corporation, James G. Terry, M.D., the State Bureau of Narcotic Enforcement, the State Division of Adult Parole, and all their authorized agents from any and all liability resulting or which may ever in any manner result from the administration of any of the above named injections, and/or tests.

Signed: ————————

Dated: ————————
Witnessed by:
1. ————————
2. ————————

Next, a history is taken. This history will include the suspect's story of addiction which should be viewed critically. A physical examination is made to rule out any deviations from normal. The physician should note the presence or absence of needle marks. The arms, hands, legs, and feet are

primary sites for marks; the abdominal wall, buttocks, scalp, and nose are secondary choices. Tattoos over the anticubital fossa sometimes are placed there to cover needle marks. The medical form used is shown in Figure 2.

Figure 2. Medical Report Form—Narcotic Cases

Date Tested _____ MEDICAL REPORT Parole Yes—No— Prob. Yes—No—

Parole/Prob. Officer _____

SUSPECTED USER OF NARCOTIC DRUG

Name: _____ Address: _____
Age: ___ Sex: ___ Race: ___ Married or Single ___ Occupation: _____
Arrest Date: _____ Location of Arrest: _____
Location of Examination: _____ Doctor making Examination: _____

NARCOTIC HISTORY

Does patient admit use of narcotics: _____ What Type: _____
Date patient first used: _____ Largest amount used daily: _____
Last two dates narcotics were used: Day—Month—Year—Amount—Paper/Cap
Day—Month—Year—Amount—Paper/Cap
Location last used _____ Method used: Hypo——Oral——Inhalation——
Scars:
Right Arm—Inner Elbow—Above Inner Elbow—Below Inner Elbow—Wrist—Hand—
Outside Arm— Other Areas _____ How many fresh scars: _____
Left Arm—Inner Elbow—Above Inner Elbow—Below Inner Elbow—Wrist—Hand—
Outside Arm— Other Areas _____ How many fresh scars: _____
Witness_____

PHYSICAL EXAMINATION

B.P. _____ Pulse: _____ Respiration: _____
Chest: _____ Abdomen _____ CNS: _____
Needle marks or scars: _____
(Describe fully)
Is Nalline contra-indicated: _____
Eyes: Pupils AC Nalline _____ PC Nalline _____ Time _____

NALLINE TREATMENT

Injection: Dose_____
Results: Yawning_____ Pupillary Dilation: _____
Gooseflesh_____ Vomiting _____ Other _____
Is treatment positive: _____
Morphine Sulfate: _____mg. Time: _____
Remarks: _____

Signed: _____M.D.

Then the diameter of the pupil of the suspect's eye is measured under conditions of constant illumination.* Nalline is

* The pupils are measured with a "pupillometer" which is a 1 x 3 inch card that contains a series of solid black dots varying in diameter from 1 to 5 mm. With a little practice the size of the pupil can be measured to within 0.5 mm. Jenkel-Davidson Optical Company furnished the pupillometers for the study.

administered subcutaneously in a dose of 3 mg. Not less than thirty minutes later the diameter of the same pupil is measured again. (1) If the person tested has not been using opiates, the diameter is reduced by 0.5 mm. to as much as 2 mm. Any measurable constriction of the pupil is considered a negative response. (2) In a person who has been using opiates occasionally but who is not addicted, the pupils will remain approximately the same. (3) In a person who is addicted, the diameter of the pupils will increase by from 0.5 mm. to 2 mm., the amount of increase depending upon the degree of addiction. In cases of gross addictions, withdrawal symptoms of Plus 4 magnitude (5)—gooseflesh, yawning, nausea, and vomiting—will preceed pupillary dilation. As soon as withdrawal symptoms of this magnitude appear, methadone, 20 mg., should be administered. Dilaudid, 8.0 mg., is preferred by and may be requested by heroin addicts, but methadone is adequate and has a more lasting effect.

Uses and Results

Since April 1956, this test has been used by the Police Department of the City of Oakland, California, in the following ways:

(1) Detection of narcotic users for criminal prosecution. From April 1956, to January 1957 (nine months) 377 persons were given a total of 744 Nalline tests. 180 (47.7%) were found to be using or addicted to narcotics. This is to be compared with only 29 persons detected in the entire year of 1955.

(2) As a control measure for narcotic violators on parole or probation. During the same nine month period, 39.6% of the persons brought in for testing were on probation and 13.5% were on parole. Of those on probation only 36% were found to be using narcotics. Of those on parole, 55.4% were found to be using narcotics. Certainty of detection accompanied by certainty of punishment is a deterrent to returning to the use of narcotics.

(3) As an aid to the Department of Motor Vehicles. A person who has had his operator's license revoked for a narcotic violation, when he reapplies for this license, must take the Nalline test 4 times at predetermined intervals before the license is restored. Those who have not appeared for the test have also not attempted to obtain their licenses.

The Nalline test can also be used:

(4) As an objective evaluation of the effectiveness of addiction cure programs. A group of 27 parolees in Los Angeles were attending a group therapy program. 85% orally reported that they were not using narcotics. All were given a Nalline test and 75% were found to be using narcotics.

(5) As a method for early detection of beginning users for purposes of rehabilitation. Since 9.7% of all the persons brought in for testing by the Oakland Police Department were under 21 years of age and 56% were in their twenties, this could become an important use.

The use of the Nalline test by the Oakland Police Department is a contributing factor in an 8.3% decrease in major crimes in Oakland. Crimes usually committed by addicts have decreased by the following amounts: *

Thefts from locked automobiles	56%
Thefts from unlocked automobiles	40%
Shoplifting	21%
Confidence games and bunco	34%
Prostitution	41%

Legal Aspects

The courts of the City of Oakland have not only accepted the Nalline test as evidence of narcotic use, but the judges have made the taking of this test a condition of probation.

Of the first 100 persons charged with violation of Section 11721 of the California Health and Safety Code (Addiction) as a result of a positive reaction to Nalline, 15 entered a plea of "Not Guilty" and requested trial. 14 were convicted and 1 was found not guilty. Since the article was published in California Medicine (4) in November 1956, there has been only an occasional trial, the great majority of defendants entering a plea of guilty.

The Public Defender's Office and some private attorneys have sent their clients in to be tested, indicating an acceptance of the test by the defense.

The three points most frequently brought up by defense attorneys to challenge this method are as follows:

* Oakland Police Department Statistical Bureau.

(1) Possible variance in lighting conditions at the time the pupils are measured. Consequently a fixed lighting arrangement has been installed which insures uniform light conditions.

(2) Efficacy of the pupillometer. Demonstration that the pupillometer measures area and reads in diameter minimized this objection.

(3) The test is experimental and is not used anywhere except in Oakland. Publication in California Medicine has de-emphasized the first point. Other cities in California are organizing Nalline programs and cities in other states are showing an interest. Dissemination of information and wider use of the test will eliminate the latter point.

Nalline provides two legal advantages in California courts. (1) Since the suspect voluntarily takes the test and signs a waiver, it has not been necessary to prove the legality of the arrest. (2) When charging "illegal use of narcotics," California courts require proof that the narcotic was used in the jurisdiction of the trial court. A positive reaction to Nalline is construed as being under the influence of narcotics and eliminates the problem of venue.

Conclusion

Nalline has proved to be a helpful and safe procedure in diagnosing narcotic use and addiction. The recommended dose of 3 mg. is small; therefore a small proportion of cases may be missed, but Nalline in this amount can be given safely. It is not our desire to produce unnecessary discomfort and pain, but rather to make a rapid and painless diagnosis.

Detecting the narcotic user and controlling the use of narcotics by those on parole or probation can be of value not only to the law enforcement agencies and the public, but also to the narcotic user himself. The Nalline test is more than just a diagnostic weapon. It has provided sufficient motivation for many beginning addicts to remain away from narcotics, and has been the motivating factor in keeping addictions to a minimum in some who have used narcotics for a period of years. In this sense Nalline is therapeutic. It is only in a noncustodial environment that the true efficacy of therapy can be established.

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Identification of Tetanus Toxin in Tissues[1,2]

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A diagnosis of tetanus is frequently of paramount importance in medicolegal medicine. The necropsy findings in this disease leave much to be desired from a definitive point of view. Tissue gram stains are frequently not of help, and culture of the organism can be quite difficult. Positive identification requires meat and litmus, milk under paraffin, or a hydrogen jar; and isolation is not always successful. Since this organism is ubiquitous, is culture of the organism sufficient to say that a given patient died of tetanus? However, if a patient has succumbed to tetanus; tetanus toxin should be present in the wound. Tetanus toxin is fairly stable though proteolytic enzymes attack it, and if the right conditions prevail, it is converted to a toxoid. This is of no consequence as the toxoid will react with the tetanus antitoxin.

There are two main serological procedures available for the identification of tetanus toxin in tissues—capillary precipitin and agar stabilized precipitin. The first is the simplest while the latter is more sensitive. We have, on occasion, in the study of anaphylactoid deaths had a case where the capillary precipitin was negative and the agar diffusion was positive, though both of these were set up with the very same materials. The fact that tetanus toxin and antitoxin combine to form a specific precipitate forms the basis for both tests. In the

[1] This research was supported in part by a grant from the National Heart Institute, National Institutes of Health, U. S. Public Health Service [H–1908].

[2] Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 2, 1957, Chicago, Illinois.

capillary technique layering is done in capillaries so that an interface is formed. The precipitate occurs at this interface. Some antigen-antibody systems in the capillary precipitin technique do not form a clearly visible precipitate at the interface but rather lead to a fine opalescence throughout the tube. However, when these are studied with agar stabilization, the slower diffusion rate allows a more even combination and a line of precipitate will form. The agar diffusion technique is more complex. Either the antigen or antibody is incorporated into agar at the base of a small tube. When this has solidified, a zone of neutral agar is placed in the tube. Then the other component, liquid, is layered on top. Diffusion of both components takes place and the antigen-antibody combination causes a specific precipitate in the neutral zone. Multiple antigens in the same system may be studied in this system because with each non-cross reacting antigen-antibody system there will be a separate precipitation. This allows the study of multiple component systems, such as a case of coexistent tetanus and gas gangrene infection. This identification can be made with a polyvalent antiserum containing both tetanus and gas gangrene antibodies. If a polyvalent antiserum is used and one precipitin occurs for each component, then all of the components of the system must be present. Each component must be tested separately if there is a missing component.

Procedure

Preparation of Antigen: The wound should be excised and the necrotic portion makes the best preparation. Macerate the necrotic material with a glass slide or a sharp knife. Make the tissue pieces as small as possible. This may also be done in a homogenizer but should be done only in a metal container or one which can be autoclaved as the positive toxin case will also have live clostridia. Dilute the homogenate with distilled water. Unless the material is fairly abundant, use only 5–10 ml. of distilled water. Let the preparation stand for about an hour for the toxin to diffuse into the water unless the homogenization is very complete. Centrifuge or filter to obtain a clear fluid.

Antitoxin: Commercial antitoxin is suitable. Most tetanus cases will have had antitoxin and may have developed horse serum antibodies. However, different commercial antisera differ in their reactivity as far as horse serum is concerned, so that this must be checked before using a given antiserum without a horse serum control. If one makes his own antitoxin in rabbits through tetanus immunization, and absorbs the antiserum with pooled normal serum, this would obviate the question of species precipitation.

Capillary Precipitin

Materials:

1—Modeling clay.

2—Capillary melting point tubes, open at both ends.

3—Specific antitoxin as above.

4—Tissue homogenate as above.

5—Stiff piece of cardboard on which to put clay.

6—Distilled water.

7—Incubator 37°C. and refrigerator [not necessary as reaction will proceed at room temperature].

No attempt is made to keep sterile as tissue homogenate will usually be grossly contaminated.

Make dilutions of the tissue homogenate in multiples of 10. As a usual rule 1:1 million is enough. Fill capillary to about one-half of its length. This is done by capillary attraction and slightly tilting the tube containing the tissue homogenate. Place finger over the tip and wipe the capillary with a clean cloth. Then allow the antitoxin to enter the capillary through the bottom and thus push the tissue homogenate to the top. Be sure that an even interface is present and there is not a bubble at the junction. Place finger over the top to keep contents from spilling and place upright in the clay. Repeat for all dilutions. Place in the incubator for two hours and in the refrigerator overnight. Reaction should begin in 5–10 minutes and can be run entirely at room temperature. Read in oblique light. Read the highest dilution in which a white precipitate is seen at the interface. In some cases the pre-

cipitate may become so heavy that it will fall to the bottom of the tube, occasionally it may rise.

Agar Stabilization

Modified from Gispen (1)

Materials:

1—1.6% agar in distilled water. Autoclave or boil before use to kill any bacteria which might be present, also this helps to clarify the agar.

2—Kahn tubes, or other small test tubes, with stoppers.

3—Test tube racks.

4—Antigen and antibody as described above.

The best results are obtained with the antigen in the liquid phase and the antibody in the agar.

Procedure:

1—0.2 ml. of standarized antitoxin is diluted to 8.0 ml. with 1.6% agar which has been cooled to just below 60° C.

2—Transfer 1 ml. of this mixture to each of eight tubes and allow to harden at room temperature. [This usually takes about 10 min.]

3—Layer 1 ml. of 1.6% agar [neutral zone] over the antitoxin and agar mixture. Allow to harden at room temperature.

4—0.1 ml. of the antigen [tissue homogenate] and dilutions as described above is layered over the neutral zone.

5—Tightly stopper each tube. Place in a rack at room temperature for development.

The time of appearance of the precipitates will vary somewhat with the rate of diffusion which is coupled with the temperature. In general the best development will be from 12 to 18 days. The lines will appear in the neutral zone. Heavy reaction will appear as solid rings and lighter reactions will appear as true rings with holes in them. It is well to study the reaction every few days because we have seen rings disappear. This is probably under the influence of antigen or antibody excesses.

Cases *

Case 1. Negro female, 55, was alighting from a bus. Several cars had stopped behind the bus. The last car in the line had a brake failure, causing an accident. The patient was thrown to the ground, resulting in a compound fracture of the right tibia. She was taken to a hospital; where after cleansing, open reduction was performed. The patient developed clinical signs of tetanus about the fourth day and died on the seventh day. At necropsy a wound infection was present with much necrosis of tissue. A capillary precipitin of wound tissue homogenate versus tetanus antitoxin was positive 1:100,000. No precipitin occurred in the tissue homogenate versus horse serum. Clostridium tetani was cultured from the wound.

Case 2. Negro female, 11, stuck a splinter in planter aspect of her left foot while playing in the street four days prior to admission. No treatment was given, and the area was tender until admission to the hospital. Admission symptoms included trismus, with stiff neck and back. Given a total of 30,000 u TAT intravenously and 30,000 intramuscularly tracheotomy, gastrostomy, and debridement were performed. Cl. tetani was cultured from the debridement material. Patient died on the fourth hospital day following a downhill course. Capillary precipitin was positive 1:10,000.

Case 3. Negro male, 9 years of age, stuck a rusty nail in right heel three days prior to admission. On the morning of admission, he awoke stiff all over and unable to open his mouth. He had had no previous immunizations. Died on the third hospital day having rereceived 50,000 u TAT intravenously and the same amount intramuscularly. Cl. tetani culture positive and capillary precipitin positive 1:10,000.

Case 4. Negro male, 60 years of age, stuck a splinter in left palm one week previous to death. He received "shots" at that time. He complained of some stiffness of the neck on the morning of death and died while visiting a friend. At necropsy a small necrotic focus was found in the depths of the puncture wound. Culture and precipitin for tetanus both positive.

Case 5. Negro male, 28 years of age, with a history of clinical tetanus. Due to a misunderstanding only blood was saved at necropsy. Precipitin and culture for Cl. tetani both negative.

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* Cases Nos. 6, 7, 8, 9 and Control Case 1 were furnished through the kindness of Drs. J. H. Davis and S. H. Durlacher, Office of the Medical Examiner, Dade County, Miami, Florida. Cultural work was performed by Dr. Marion Hood, Microbiologist, Department of Pathology, Charity Hospital, New Orleans, Louisiana.

Case 6. White male, 59 years old, cut his thumb sawing wood. Suture was the only form of therapy. Seven days later there was stiffness of the neck and difficulty in opening his mouth. He was admitted to the hospital the following day. Death occurred four hours after hospital admission. Was given 120,000 u TAT. Both the agar stabilized precipitin and culture positive.

Case 7. Negro female, four years of age, lacerated finger in bicycle chain. Died of clinical tetanus 14 days later. There had been no previous immunizations. Treated with 60,000 u TAT. Both the precipitin and culture for Cl. tetani positive.

Case 8. Twenty-one-year-old Negro male had stiffness of jaw with increasing difficulty in breathing and hyperirritability. Died in the emergency room before treatment could be instituted. At necropsy a small superficial ulcer of the right medial malleolus was found. A small amount of purulent material was elicited on pressure. The origin of the lesion is vague. Relatives state that the deceased mentioned hurting his ankle a couple of weeks before. Both the precipitin and culture for Cl. tetani positive.

Case 9. Negro male, twelve days of age, was born in the hospital, discharged, and re-entered the hospital at the age of ten days with signs of clinical tetanus. Died after two days in the hospital. Impression tetanus of the umbilical stump. Both culture and precipitin negative.

Case 10. Negro male, 65 years of age, had severe arteriosclerosis, and developed gangrene with ulceration of the third toe of the right foot, approximately one month prior to admission. He was being treated symptomatically and amputation was being considered. He came to the outpatient clinics of the hospital two days and four days prior to admission. On both of these occasions the process was thought to be arteriosclerotic gangrene. On the day of admission, the patient could not open his mouth to insert his false teeth, and complained of a stiff neck. He received a low thigh amputation, 100,000 u TAT intravenously and 100,000 u intramuscularly. He died the following morning. Both the precipitin and culture for Cl. tetani were positive.

Case 11. Seventy-four-year-old Negro male had severe arteriosclerosis and underwent the above type-knee amputation for arteriosclerotic gangrene of the left leg six months previously. He was seen in the accident room with opisthotonos, facial trismus, and a putrid right foot. Given 25,000 u TAT intravenously and 25,000 u intramuscularly, and the right leg was packed in ice. He expired during mid-thigh amputation. Both the precipitin and culture for Cl. tetani were positive.

Control Cases: These cases had wounds which were necrotic and similar to those seen in tetanus.

Case 1. Adult patient had bilateral necrotic leg ulcers. There was only slight clinical suspicion that the clinical course was due to tetanus. The precipitin against TAT and culture for Cl. tetani were both negative.

Case 2. Negro male, 62 years of age, had sustained multiple fractures of the legs in an automobile accident about three months previously. Just prior to death, he was transferred to a hospital within our parish for urinary retention. Nothing in the history to suggest tetanus. Both precipitin and culture negative.

Discussion: We now perform all of our tetanus precipitin tests with the agar stabilization technique, because we have found this more sensitive and allows simultaneous study of multiple antigen-antibody components. The demonstration of the toxin in tissue should be more specific in the diagnosis of the disease than the presence of a positive culture, because of the ubiquity of this organism. In all cases in which wound material was available, where culture has been positive for Cl. tetani, the precipitin for toxin has been positive. The material from Case 9 was quite dry and perhaps this caused denaturation of the toxin. The culture was negative for Cl. tetani. This illustrates a case in which the organism was not recoverable and is the type of case in which the precipitin test would be most valuable. We have no case of positive precipitin without positive culture. The highest concentration of toxin would be expected in the wound with the organisms. This test has not been positive in our experience when performed on the blood of these patients. But we have not yet been able to get blood from a patient who had not yet received intravenous antitoxin. About fifteen per cent of the cases of clinical tetanus have no specific wound or necrotic lesion, at least none can be found. Thus there is a group of patients in whom this test will probably be negative.

This type of precipitin technique will form a useful adjunct to the forensic pathologist in his study and proof of this diseased state. This is especially true in an instance where bacteriologic facilities may be lacking or the organism fail to grow for some reason.

Summary

1. Two methods of precipitin testing for the presence of tetanus toxin in tissues have been presented—capillary and agar stabilized. The second is more sensitive and allows the study of multicomponent systems.

2. Results with this method in 11 cases of clinical tetanus are presented.

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Office of the Coroner, Parish of Orleans, and the
Departments of Pathology of Louisiana State
University School of Medicine and the Charity
Hospital of Louisiana, New Orleans, Louisiana

American Academy of Forensic Sciences

CONSTITUTION

ARTICLE I—NAME

The name of this organization shall be the American Academy of Forensic Sciences.

ARTICLE II—OBJECTIVES AND PURPOSES

The objectives and purposes of this Academy shall be to encourage the study, improve the practice, elevate the standards, and advance the cause of the forensic sciences; to promote the standardization of scientific techniques, tests and criteria; and to plan, organize, and administer meetings, reports and other projects for the stimulation and advancement of these and related purposes.

ARTICLE III—ELIGIBILITY FOR MEMBERSHIP

Academy membership, in the various classifications subsequently prescribed, shall be available only to those persons of professional competency, integrity and good moral character

a) who are actively engaged in the field of forensic science and who have made some significant contribution to the literature of forensic science; or
b) who have advanced the cause of forensic science in some other significant manner; or
c) who are pursuing a career which has as its purpose the attainment of either of the foregoing objectives (a) or (b).

ARTICLE IV—MEETINGS

An Annual Meeting shall be held at a time and place selected by the Executive Committee, constituted as provided in the By-Laws. At the Annual Meetings, for which ten percent of the total number of voting members shall constitute a quorum, there shall be a scientific program, an election of officers, and the transaction of such business as may be necessary. Other meetings may be called at the discretion of the Executive Committee.

ARTICLE V—OFFICERS

The officers of this Academy shall consist of a President, President-Elect, and Secretary-Treasurer. These officers shall be elected at

the Annual Meeting and shall hold office for one year or until their successors shall have been elected and qualified.

ARTICLE VI—AMENDMENTS

Any Article of this Constitution, or any provision of the By-Laws, may be amended by a three-fourths vote of the voting members present at any regular Annual Meeting, provided that copies of each proposed amendment shall have been mailed to all voting members at least thirty (30) days in advance of the Annual Meeting at which final action is to be taken.

BY-LAWS

CHAPTER I—MEMBERSHIP

Section 1.

There shall be five classes of membership in the Academy:

a) Fellow
b) Provisional Member
c) Retired Fellow
d) Associate Member
e) Corresponding Member

The qualifications for the various membership are as follows:

a) *Fellow.* All present members of the Academy other than Provisional Members, Corresponding Members, and Associate Members, who are in good standing at the time of the adoption of this amendment, shall be classified as Fellows. Thereafter it shall be the function of the Executive Committee to determine which of the present or future Provisional Members or Associate Members should be classified as Fellows; and in the making of that determination consideration shall be given to the member's efforts and attainments in the field of forensic science and his interest in the objectives and purposes of the Academy as stated in Article II of this Constitution.

b) *Provisional Member.* Every person elected to membership shall be classified as a Provisional Member for one (1) year. At the end of his one-year period as a Provisional Member, such member, at the discretion of the Executive Committee, may be made a Fellow or an Associate Member, or continued as a Provisional Member, or dropped from Academy membership. Any such decision of the Executive Committee shall be final and not appealable to the general membership.

c) *Retired Fellow.* A Fellow who has had twenty-five (25) consecutive years of service with the Academy, or who has reached the age of seventy (70), may be classified by the Executive Committee as a Retired Fellow, who then shall be excused from

all fees and dues, but he shall retain all the privileges of a Fellow.

d) *Associate Member.* Any person who is pursuing a career as a laboratory technician or research assistant in some field of forensic science, or who is engaged in some related activity and has a substantial interest in one or more of the forensic sciences, as well as an interest in the objectives and purposes of this Academy, is eligible as an Associate Member. Associate Members may attend any of the Academy's scientific or social meetings, and they may serve as Section members as well as on special committees to which they may be appointed; but they shall not be privileged to hold Academy offices or vote at general Academy meetings. Their dues shall be one-half that specified for Fellows.

After three (3) consecutive years in good standing, Associate Members are eligible for classification as Fellows at the discretion of the Executive Committee.

e) *Corresponding Member.* Present members of the Academy who are in good standing, and who reside outside of the continental United States and Canada, may accept the status of Corresponding Member and thereby be excused from the payment of dues, but they shall not be eligible to vote or hold office. Additional Corresponding Members may be appointed from time to time within the discretion of the Executive Committee.

Section 2.

As herein used, the word member shall refer to any one in the foregoing classifications of membership. The term "voting member," however, shall refer only to Fellows, and Retired Fellows.

Section 3. Applications for Membership

a) Applications for membership shall be made upon the forms furnished by the Secretary-Treasurer, and the applications shall be endorsed by letters from two members, which letters shall be sent directly from the endorsers to the Secretary-Treasurer. Both the application form and letters of recommendation must be made in duplicate. No applicant whose application is incomplete in any way or whose letters of recommendation have not been received on or before September 15 preceding the Annual Meeting shall be considered for membership at that meeting.

b) The Secretary-Treasurer shall send to all members, before October 15, a list containing each applicant's name, address, position, and a brief sketch of the applicant's professional background. This data shall be accompanied by an invitation to all members to submit any pertinent information they may possess regarding the applicant's qualifications for membership. The Secretary-Treasurer shall also forward all applications and en-

dorsing letters to the Chairman of the Membership Committee on or before October 15.

c) The Membership Committee shall investigate each applicant's qualifications and make a complete report on all pending applications to the Executive Committee on or before January 1.

d) The list of the names of all applicants, reported favorably upon by the Executive Committee, shall be presented to the voting membership at the Annual Meeting for final approval.

Section 4.

a) Any member whose professional or personal conduct becomes adverse to the best interests and purposes of the Academy shall be liable to censure, suspension or expulsion. Charges against a member must be in writing and delivered to the Secretary-Treasurer, who shall immediately furnish copies to the accused and to the Ethics Committee. The Ethics Committee shall investigate the charges and report its findings to the Executive Committee, but no action shall be taken by the Executive Committee until the accused and the accusers have had a reasonable opportunity to be heard.

Upon an unanimous vote of the Executive Committee the accused may be censured, suspended or expelled, but the accused shall have a right to appeal to the voting membership of the Academy. In effecting an appeal, the appellant must file a brief typewritten notice of his appeal, together with eight legible copies of any typewritten statement he may wish to submit in his behalf, with the Secretary-Treasurer not less than sixty (60) days prior to the next Annual Meeting. The Secretary-Treasurer shall immediately advise each member of the Executive Committee of the appeal, and forward to each one a copy of the supporting statement submitted by the appellant. The Executive Committee shall then prepare a written statement of the reasons for its action and file the same with the Secretary-Treasurer not less than forty (40) days prior to the approaching Annual Meeting. Within ten (10) days thereafter, the Secretary-Treasurer shall mail to each voting member of the Academy a copy of the appellant's notice of appeal and his supporting statement, if any, and a copy of the Executive Committee's statement.

A vote of three-fourths of the voting members registered at the Annual Meeting shall be required to overrule the action of the Executive Committee in regard to censure, suspension, or expulsion of a member.

CHAPTER II—GOVERNMENT

Section 1.

The general management of the Academy, including levying of dues and assessments, shall be the responsibility of an Executive Committee,

which shall consist of the President, the President-Elect, the immediate Past-President, the Secretary-Treasurer, and three Fellows-at-large. The term of office for each Fellow-at-large shall be three years, and their elections shall occur upon the expiration of the terms of office of the present Fellows-at-large.

A quorum of the Executive Committee shall consist of at least five (5) of its members and any order of the Executive Committee shall not be passed unless the motion shall have at least four (4) assenting votes.

Section 2.

The President shall preside at the meetings of the Academy and the Executive Committee, and shall perform such duties as custom and parliamentary usage may require.

Section 3.

The President-Elect shall assist the President in the performance of his duties. He shall act for the President in his absence or disability, and if the office of President becomes vacant, the President-Elect shall then succeed to the Presidency to serve as President for such unexpired term and for the term of one year thereafter.

Section 4.

In case of vacancy in the office of both President and President-Elect, the Executive Committee shall elect a Fellow to serve as President until the election of a successor at the next Annual Meeting of the Academy.

Section 5.

The Secretary-Treasurer shall record the minutes of the meetings and receive and care for all records and papers belonging to the Academy. He shall notify each member of the Academy of the time and place of the meetings and state the program. He shall keep account of and properly safeguard all funds of the Academy which come into his hands. He shall keep a list of the members of this Academy in good-standing, noting each member's correct address.

Section 6.

All officers shall be elected at the Annual Meeting and shall assume office immediately thereafter.

Section 7.

Although all members shall be privileged to attend and participate in any of the Academy's scientific sessions or social functions, the business sessions of the Academy shall be open only to Fellows and Retired Fellows, and only they may vote or hold office.

CHAPTER III—COMMITTEES

Section 1.

In addition to the Executive Committee, the Academy shall have a Council, an Ethics Committee, and certain standing and special committees, as hereinafter provided.

Section 2. Council.

The Council shall consist of the Chairman and Secretary of each Section, as such Sections are hereinafter defined, and the Council shall act as advisor to the Executive Committee with respect to the interests of the various Sections.

The Chairman and Secretary for each year's Council shall be the Chairman and Secretary of each Section in annual rotation according to the alphabetical listing of the various Sections.

The Council shall meet one or more times during the Annual Meeting of the Academy, and whatever reports or recommendations it may prepare for the consideration of the Executive Committee shall be submitted in writing to the Secretary-Treasurer of the Academy for presentation to the Executive Committee.

A quorum of the Council shall consist of a majority of its members.

Section 3. The Ethics Committee.

There shall be an Ethics Committee consisting of three Past-Presidents, one of which shall be designated to serve as Chairman.

Section 4. Standing and Special Committees.

There shall be the following standing committees:

a) Educational
b) Membership
c) Nominating
d) Program
e) Publications
f) Public Relations

With the exception of the Membership Committee, on which each Section shall have a representation, the other committees shall each be composed of three (3) Fellows.

The report which the Membership Committee shall submit to the Executive Committee must disclose the numerical vote of the Committee members with respect to each applicant.

Except for the Nominating Committee, the President shall make all appointments to the various committees. The Nominating Committee shall be appointed by the Executive Committee not later than the noon hour of the first day of the Annual Meeting.

The Nominating Committee shall submit to the membership, at the business session of the Annual Meeting, a list of nominees, which shall consist of at least one nominee for each office to be filled. Additional nominations may thereupon be made from the floor.

CHAPTER IV—SECTIONS OF THE ACADEMY

a) The entire membership of the Academy, insofar as it is feasible, shall be assigned to Sections on the basis of their expressed desire in accordance with their specific interest in various fields of forensic science.

b) A Section is defined as a group of ten (10) or more members mutually interested in a specific field of forensic science.

c) Any ten (10) members may petition the Executive Committee for the establishment of a new Section.

d) The Executive Committee may establish whatever Sections it may deem desirable.

e) Each Section shall have a Chairman and Secretary, of the rank of Fellow. The Chairman of each Section may appoint committees within the Section.

f) Sections shall not levy dues, nor shall any Section incur Academy expense without specific authorization from the Executive Committee, nor shall any Section conduct surveys or indulge in any other activity or undertaking outside the Academy without approval of the Executive Committee.

g) The first order of business of a Section at the Annual Meeting shall be the nominations for its Chairman and Secretary. Elections shall be held just prior to the adjournment of the Section meeting, and the Secretary-Treasurer of the Academy shall be informed in writing of the results of the election.

h) Each Section shall have available from the treasury of the Academy up to ten (10) percent of the annual dues paid to the Academy by members of the Section for carrying out Section business; this shall be based on dues assessed and collected for the fiscal year of the Academy in which the meeting is held. No such funds shall be expended, or any financial obligations incurred, however, without approval of the Executive Committee.

CHAPTER V—FUNDS AND EXPENSES

Section 1.

Funds for meeting the expenses of the Academy shall be raised by annual dues, assessments, voluntary contributions, and such income as may come to the Academy through the collective efforts of its members. No financial obligations of the Academy, however small, may be incurred by any one or any group of members, except upon prior authorization of the Executive Committee, and disbursements by the Secretary-Treasurer may be made only upon the authorization of the Executive Committee.

Any member who shall fail to pay his annual dues and/or other obligations by the first of October of the current fiscal year shall be automatically dropped from the roll of members, and may be re-

admitted only upon the filing of a new application, which shall receive the same, but only the same, consideration as is customarily given to other applications.

Section 2.

The fiscal year of this Academy shall be from January through December, inclusive.

CHAPTER VI—RULES OF ORDER

Section 1.

The rules contained in the POCKET MANUAL OF RULES OF ORDER, by Henry M. Robert, shall determine the parliamentary practice of the Academy in all cases to which they apply, and when they are not inconsistent with the Constitution or By-Laws of the Academy.

As amended February 28, 1957.

As directed for publication by the Executive Committee of the American Academy of Forensic Sciences.

Book Review

INDUSTRIAL TOXICOLOGY (Second Edition), by Lawrence T. Fairhall, Scientist Director, Ret., United States Public Health Service. The Williams & Wilkins Company, Baltimore, 1957. 376 pages. $10.00.

The second edition of this well-known reference book on Industrial Toxicology appears in a new format of larger pages with double column, which makes for much easier reading. A number of new entries, and an appendix containing (1) a conversion table for gases [reproduced from the U. S. Bureau of Mines Technical Paper 248, 1921], (2) a table of end products of detoxication of thirty-eight compounds, (3) a table of threshold limit values [reprinted from the A.M.A. Archives of Industrial Health, 1955], and (4) a table of comparative toxicities of various substances based on the LD_{50} for oral administration to rats—increase the value of this book to a fair degree.

The material is divided into "Inorganic Substances" and "Carbon Compounds"; and with few exceptions each entry, appearing in alphabetical sequence, is considered under four headings: 1) characteristics—physical and chemical constants, method of preparation, etc.; 2) industrial uses; 3) toxicity—including comparisons with allied compounds, maximum allowable concentrations, symptoms and pathology produced in animals and man; 4) analysis—fundamentals are usually given with references to specific methods. References (which have been increased in number over the first edition) of salient literature are appended to each entry. The value of the book rests in the succint presentation of a large amount of factual material made readily available by the standardized make-up of the book. Anyone who is interested in forensic chemistry and/or toxicology should have this excellent reference book readily available.

W. J. R. Camp

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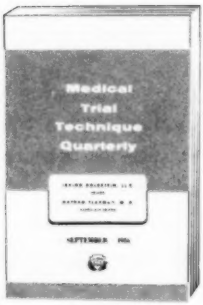

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